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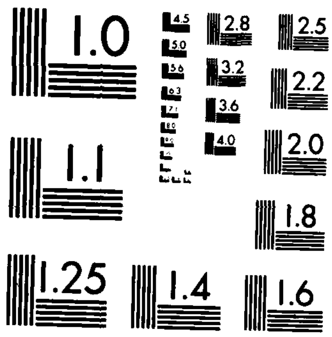

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HELICOPTER-BORNE SCATTEROMETER

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HELICOPTER-BORNE SCATTEROMETER

by

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ABSTRACT

The HELOSCAT is a helicopter-borne FM-CW radar capable of acquiring differential radar cross-section data over a wide range of frequencies (4-18 GHz), polarizations (VV, HH, HV) and angles of incidence (10° - 70°). A technical description is provided.

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1.0 INTRODUCTION

The value of all-weather, day-night radar reconnaissance of sea ice has been well established by empirical means. Such techniques are used by scientists and Arctic operators in various countries of the Arctic basin. Although aircraft radar monitoring systems are in operational use, knowledge of the nature of the interaction between microwaves and ice is still sufficiently incomplete that design of future systems cannot yet be optimized. Furthermore, this knowledge is important to a fuller understanding of the observations made both by operational systems and experimental systems, both of which are radars designed for other purposes.

The purpose of this report is to provide a detailed technical description of the University of Kansas helicopter-borne microwave active spectrometer (HELOSCAT). A major advantage of this calibrated system is the mobility of the helicopter platform--it has the advantages of both a ground-based system and an aircraft system without many of the inherent disadvantages. The Bell 206 helicopter was chosen as the best platform because of its wide availability in the High Arctic (and continental U.S., for that matter) and its low operating cost when compared to its sister aircraft, the Bell 205 and 212. Costs are in the range of $350/flight hour with a fuel consumption of 30 gallons per hour. In contrast, the larger Bell 205 costs are $1000/hour with a fuel consumption of 80 gallons per hour.

This system features the ability to acquire data at frequencies from 4 to 18 GHz with like- and cross-antenna polarizations and angles of incidence from 10° to 70°, as specified in Table 1. All control, including that of the angles and antenna polarizations, is from within the aircraft. Frequency selection may be performed both manually or via microprocessor. The microprocessor also multiplexes data from a fast true rms detector (0.1 second average) and an averaging true rms detector (1 second average). Information such as the modulation frequency of the oscillator control signal, the altitude determined by the HELOSCAT radar altimeter, a test-site code and the time of a measurement is placed onto digital cassette tape by the microprocessor. An automatic tracking loop is used to compensate for variations in aircraft altitude and attitude by locking the processing circuitry onto the target returns. Much work has been done to make the radar into a small, lightweight and easily installed package.

TABLE 1

HELOSCAT III SYSTEM SPECIFICATIONS

Type	FM-CW
Frequency Range	4-18 GHz
Modulating Waveform	Triangular
FM Swee;	800 MHz
Transmitter Power	14-19 dBm
Intermediate Frequency	50 kHz
IF Bandwidth	13.5 kHz
Antennas:	Log-Periodic Feed Reflectors
No. 1	
Size	46 cm
Polarization	VV
Beamwidths (β_e)	7.6°, 4.9°, 3.7° and 2.9° at 4.8, 7.2, 9.6 and 13.6 GHz
No. 2	
Size	61 cm
Polarization	HH
Beamwidths (β_e)	5.4°, 3.7°, 2.7° and 1.9° at 4.8, 7.2, 9.6 and 13.6 GHz
No. 1/2	
Size	64 cm and 61 cm
Polarization	Cross
Beamwidths (β_e)	6.3°, 4.2°, 3.2° and 2.3° at 4.8, 7.2, 9.6 and 13.6 GHz
Incidence Angles	10° to 70° from nadir
Calibration:	
Internal	Signal Injection (delay line)
External	Luneberg lens
Altitude	30 m for θ = 10° to 50° 15 m for θ = 60° and 70°

2.0 A BRIEF ACCOUNT OF RADAR CROSS-SECTION THEORY

A radar scatterometer is a device that accurately measures the strength of an observed signal which evolves due to the scattering properties of an observed region [1]. The radar backscatter is described in terms of the differential radar cross-section σ^o. This representation is used because backscatter is assumed to be the incoherent collection of a very large number of separate scatterers. This says that the scatterers are sufficiently randomized in the resolution cell that the received power from each may be added to the power from all the others without consideration for phase.

2.1 Modified Radar Equation

When sensing a target where the radar parameters remain essentially unchanged from one part of the resolution cell to the other, the following modified radar equation may be applied [2]:

$$P_r = \frac{P_t G_t G_r \lambda^2 \sigma^o A_{ILL}}{(4\pi)^3 R_T^4} \tag{1}$$

where:

- P_r = received power
- P_t = transmitted power
- G_t = transmit antenna gain
- G_r = receive antenna gain
- λ = wavelength
- σ^o = differential scattering cross-section per unit area
- A_{ILL} = illuminated area
- R_T = range to target

2.2 Determination of Differential Scattering Cross-Section

The power for a radar may be measured directly by use of a square-law detector. This power may be related to the returned power at the receive-antenna port through an unknown constant, K_T, which represents the effects of the receiver gain as well as the attenuation and conversion losses between antenna and detector. We can then relate the detector power, P_T, to the returned power.

$$P_T = K_T^2 \left[\frac{P_t G_t G_r \lambda^2 \sigma^o A_{ILL}}{(4\pi)^3 R_T^4} \right] \tag{2}$$

Immediately before and after recording the return from the target of interest, a coaxial delay line of loss L is switched into the circuit at the antenna ports to replace the path through the transmit antenna to the target and back through the receive antenna.

The power after square-law detection is given by:

$$P_{DLT} = K_T^{\,2} P_t L \tag{3}$$

Taking the ratios of equations (2) and (3), we have:

$$\frac{P_T}{P_{DLT}} = \frac{G_t G_r \lambda^2 \sigma^o A_{ILL}}{(4\pi)^3 R_T^{\,4} L} \tag{4}$$

As can be seen in the above equation, variations in transmitted power and the effects of variations in cable loss, mixer conversion loss, receiver gain, etc., are removed.

To complete calibration of the system, the returns from a standard target of known radar cross-section are measured. The standard radar target used in the Arctic backscatter experiments is a Luneberg lens. The returned power of the standard radar target is given by:

$$P_{LENS} = K_c^{\,2} \left[\frac{P_t G_t G_r \lambda^2 \sigma_{SRT}}{(4\pi)^3 R_c^{\,4}} \right] \tag{5}$$

where:

K_c = system constant K at time of calibration

R_c = range to standard radar target

σ_{SRT} = radar cross-section of standard radar target

The power detected through the coaxial delay line at the time of calibration using the standard radar target is given by:

$$P_{DLL} = K_c^{\,2} P_t L \tag{6}$$

The ratio of equations (5) and (6) is given by:

$$\frac{P_{LENS}}{P_{DLL}} = \frac{G_t G_r \lambda^2 \sigma_{SRT}}{(4\pi)^3 R_c^{\,4} L} \tag{7}$$

Note that variation in P_T and K_c do not appear in the ratio. Combining equation (7) with the inverse of equation (4) yields the following when solved for σ^o:

$$\sigma^o = \frac{P_T P_{DLL} R_T^4 \sigma_{SRT}}{P_{DLT} P_{LENS} R_c^4 A_{ILL}} \tag{8}$$

expressed in dB may be written as follows:

$$\sigma^o(dB) = P_T(dB) - P_{LENS}(dB) - P_{DLT}(dB) + P_{DLL}(dB)$$
$$+ 40 \log (R_T/R_c) + \sigma_{SRT}(dB) - 10 \log A_{ILL} \tag{9}$$

$P_T(dB)$, $P_{DLT}(dB)$, $P_{LENS}(dB)$ and $P_{DLL}(dB)$ are measured and recorded at the time of the experiment.

2.3 Illuminated Area

The illuminated area is calculated using the geometry shown in Figure 2.1. The projection of a radar beam in the form of an elliptical cone as seen on the ground is a skewed ellipse. The area of the ellipse is calculated as

$$A_{ILL} = \frac{\pi}{4} \text{(major axis)(Minor axis)}$$

Note that the major axis lies in the elevation plane and the minor axis lies in the azimuthal plane. From the geometry of Figure 2.1, expressions for the major and minor axes were derived.

$$M_{axis} = R_T \cos\theta [\tan(\theta + \beta_E/2) - \tan(\theta - \beta_E/2)]$$
$$m_{axis} = 2R_T \tan(\beta_A/2) \tag{10}$$

and

$$A_{ILL} = (\pi/2) R_T^2 \cos\theta \cdot \tan(\beta_A/2) \cdot [\tan(\theta + \beta_E/2) - \tan(\theta - \beta_E/2)] \tag{11}$$

where:

A_{ILL} = illuminated area
M_{axis} = major axis
m_{axis} = minor axis
R_T = range to target
θ = pointing angle of antennas off vertical
β_E = effective gain product beamwidth in the elevation plane
β_A = effective gain product beamwidth in the azimuthal plane

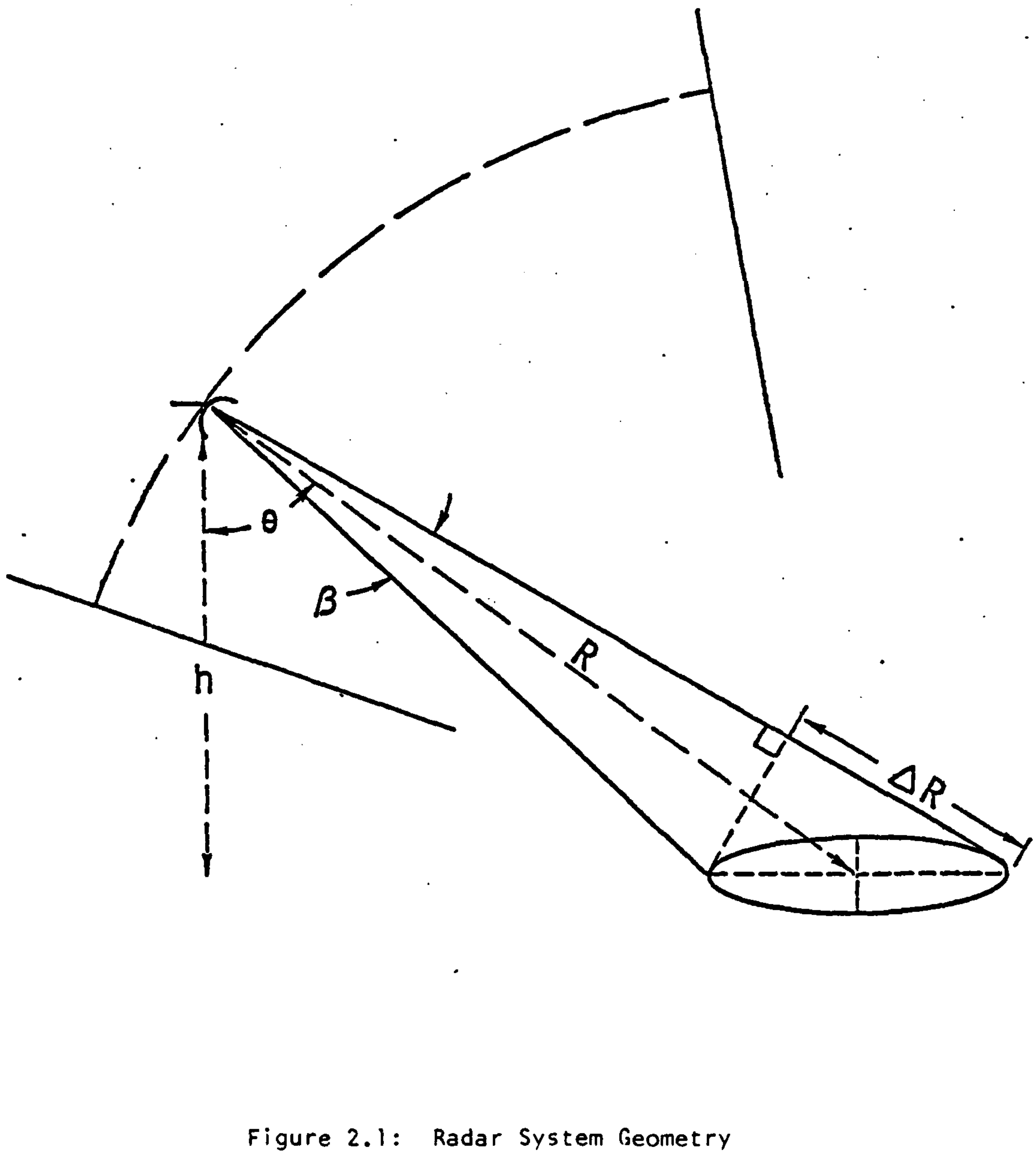

Figure 2.1: Radar System Geometry

2.4 Relationship Between Range and Oscillator Modulation Rate

For a given target at range R, the time that returned signals are delayed when referenced to the transmitted signal is 2R/c. An illustration of the frequency relationship between the transmitted and received signals for triangular frequency modulation is shown in Figure 2.2. Using similar triangles it may be shown that:

$$\frac{2R/c}{f_{IF}} = \frac{1/(4f_m)}{\Delta f/2} \tag{12}$$

or

$$R = f_{IF}c/4\Delta f f_m \tag{13}$$

where:

R = equivalent free-space range to target
c = free-space velocity of light in m/sec
f_m = oscillator modulation frequency
f_{IF} = intermediate frequency
Δf = sweep width of RF signal

However, equation (13) does not account for the delay that occurs due to the travel of the radar signal within the radar itself. To account for this delay a range term associated with this time delay, R_D, must be added to equation (13).

$$R = f_{IF}c/4\Delta f f_m - R_D \tag{14}$$

2.5 Range Limiting by IF Bandpass Filter

A bandpass filter is used in the processing of the intermediate frequency return signals acquired from the earth scene. This filter limits signal processing to the intermediate frequencies which exist within its bandwidth or, equivalently, to the scatterers which are located within a resolution cell determined by the filter bandwidth. Normally the range of the return signal intermediate frequencies is limited by the filter action of the antenna pattern. However, IF filter limiting will occur when the radar beamwidth range resolution becomes greater than the IF filter resolution. The beamwidth resolution is given by:

$$\Delta R = R\cos\theta[\sec(\theta + \beta_E/2) - \sec(\theta - \beta_E/2)] \tag{15}$$

The filter resolution is given by:

$$\Delta R = \frac{R\Delta f_{IF}}{f_{IF}} \tag{16}$$

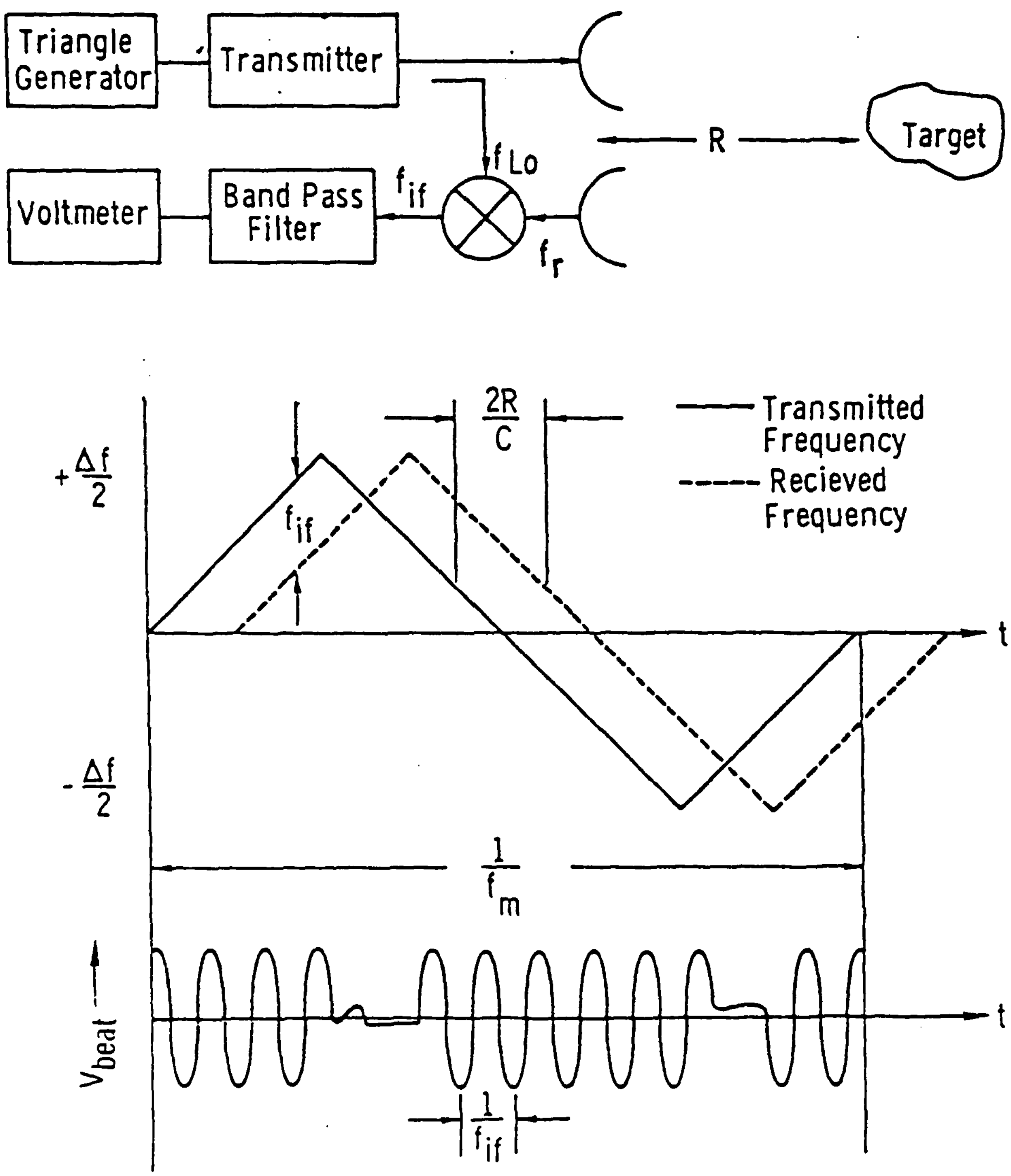

Figure 2.2: Simplified FM-CW Radar System

where Δf_{IF} = IF filter bandwidth.

If the incidence angle exceeds the value for which ΔR is the same in (15) and (16), the IF bandpass filter starts to cut off the returns from the ranges which correspond to the IF frequency of outside its bandwidth, resulting in the reduction of illuminated area. The following is a summary effect on illuminated area [3].

From Figure 2.3, a and b are the semi-major and semi-minor axes as given by equations (10) and (11). α_1 and α_2 are the range limits set by the filter and given by:

$$\alpha_1 = (R + R_D)\frac{1-\Delta f}{2f_c} \tag{17}$$

$$\alpha_2 = (R + R_D)\frac{1+\Delta f}{2f_c} \tag{18}$$

where f_c is the center frequency of the filter and Δf is the bandwidth of the filter. ℓ_1 and ℓ_2 are the distance from the center of the beam to the edges of the beam, and x_1 and x_2 are the distances to the range limits of the filter. K is the distance to the center of the ellipse. From Figure 2.3, the following equations are easily obtained:

$$\gamma = h\cdot\tan(\theta - \beta_E/2) \tag{19}$$

$$K = \gamma + a \tag{20}$$

$$\ell_1 = (h\cdot\tan\theta) - \gamma \tag{21}$$

$$\ell_2 = 2a - \ell_1 \tag{22}$$

$$x_1 = \begin{cases} h\cdot\tan\theta - \sqrt{\alpha_1^2 - h^2} & \text{if } \alpha_1 \geq h \\ h\cdot\tan\theta & \text{if } \alpha_1 < h \end{cases} \tag{23}$$

$$x_2 = \sqrt{\alpha_2^2 - h^2} - h\cdot\tan\theta \tag{24}$$

Depending on the relations between x_1 and ℓ_1 and between x_2 and ℓ_2, the following four cases can arise.

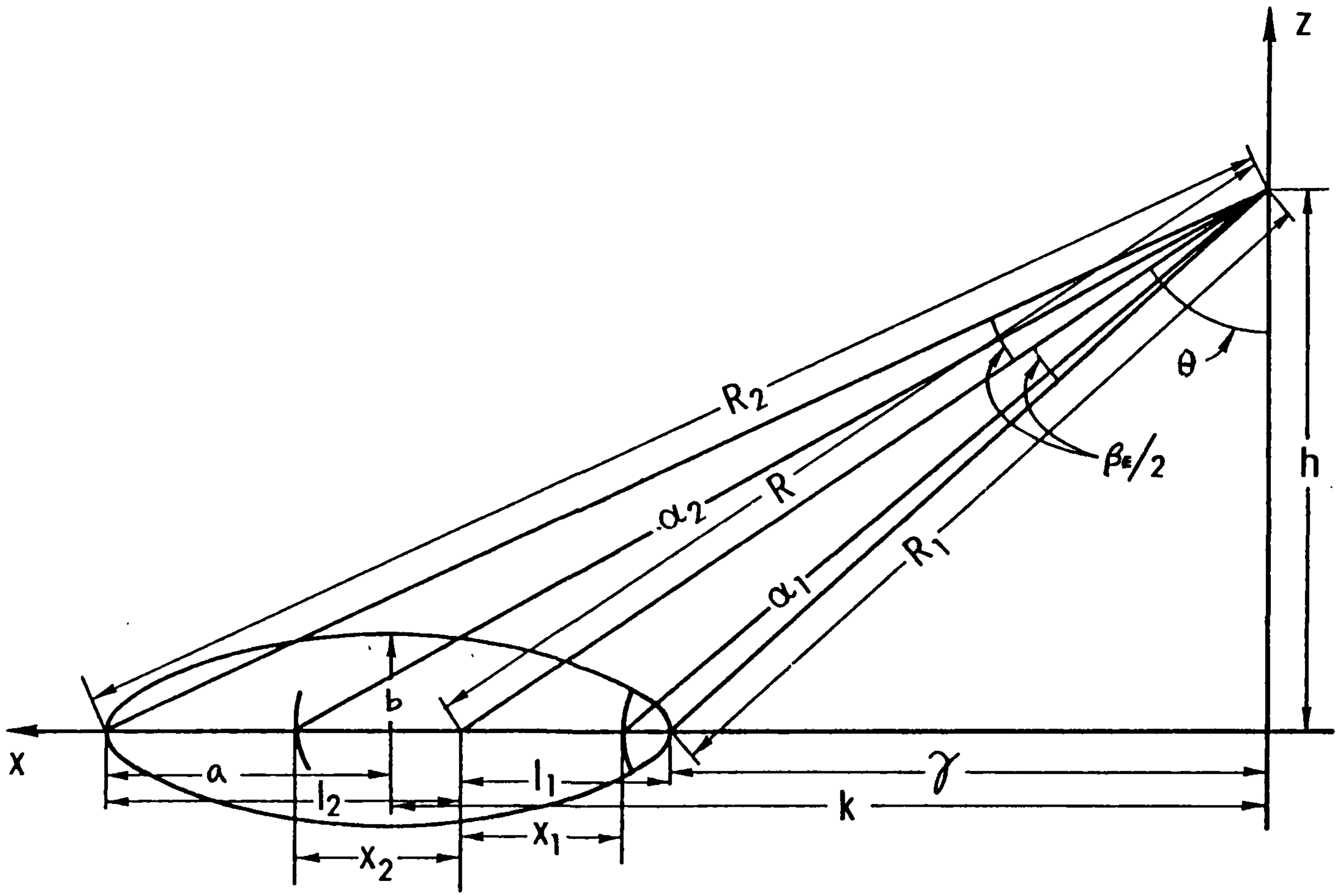

Figure 2.3: Geometric Representation of Radar Beam Showing Filter Cut-Off

Case 1:

The filter completely covers the antenna beamwidth (see Figure 2.4) when $x_1 > \ell_1$ and $x_2 > \ell_2$. This is the case treated in the beginning of this section.

Case 2:

The filter partially covers the radar resolution (see Figure 2.5) when $x_1 < \ell_1$ and $x_2 > \ell_2$.

$$G = h \cdot \tan\theta - x_1 \tag{25}$$

The equations for the ellipse and the equal range circle are given, respectively, by

$$\frac{(x - K)^2}{a^2} + \frac{y^2}{b^2} = 1 \tag{26}$$

and

$$x^2 + y^2 = G^2 \tag{27}$$

Solving these two equations for the intersection point Ψ,

$$\Psi = [Kb^2 - \sqrt{a^2b^2K^2 - a^2(G^2 - b^2)(b^2 - a^2)}]/(b^2 - a^2) \tag{28}$$

The area which should be subtracted from the whole ellipse is,

$$\text{area} = 2[\int_{\gamma}^{\Psi} b\sqrt{1 - (x-K)^2/a^2}\, dx + \int_{\Psi}^{G} \sqrt{G^2 - x^2}\, dx \tag{29}$$

Solving equation (29), we have

$$\text{area} = \frac{ab}{2}(\theta_1 - \sin 2\theta_1) + \frac{G^2}{2}(2\theta_2 - \sin 2\theta_2) \tag{30}$$

where:

$\theta_1 = \cos^{-1}((h - \Psi)/a)$

$\theta_2 = \cos^{-1}(\Psi/G)$

Therefore, the resultant illuminated area for Case 2 is:

$$A_{ILL} = \pi ab - \text{area} \tag{31}$$

where area is given by equation (30).

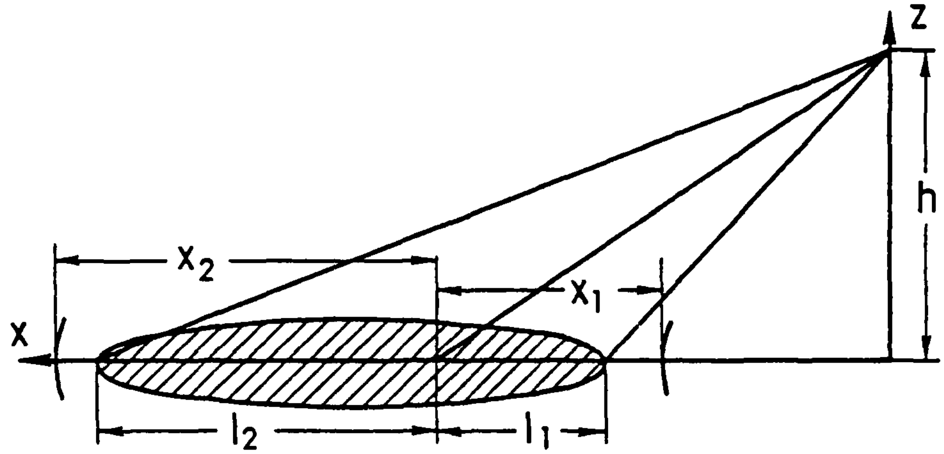

Figure 2.4: Shows Filter Completely Covering Radar Beam Resolution (Case I)

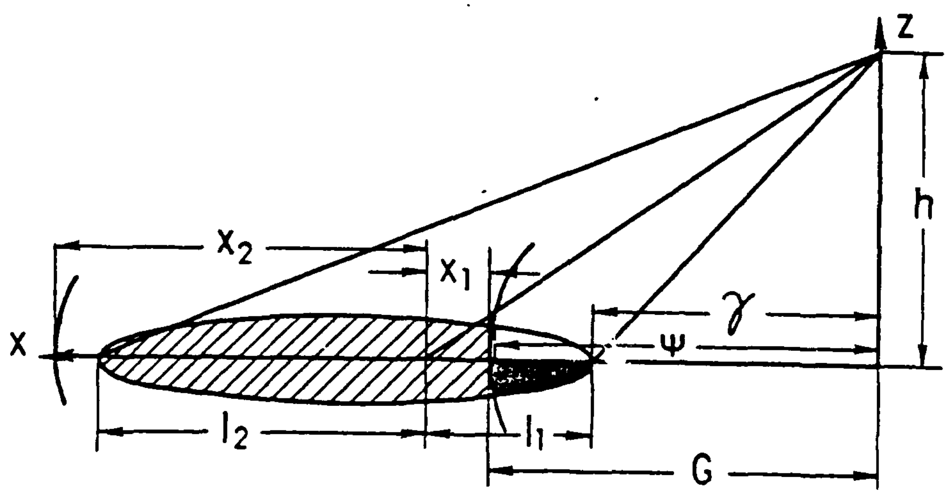

Figure 2.5: Shows Filter Partially Covering Radar Beam Resolution (Case II)

Case 3:

The filter partially covers radar resolution (see Figure 2.6) when $x_1 > \ell_1$ and $x_2 < \ell_2$. Now,

$$G = h \cdot \tan\theta + x_2 \tag{32}$$

The shaded area can be calculated along the same lines as in Case 2 and is given by

$$A_{ILL} = 2[\int_{\gamma}^{\Psi} b\sqrt{1 - (x-K)^2/a^2}\, dx + \int_{\Psi}^{G} \sqrt{G^2 - x^2}\, dx \tag{33}$$

Solving equation (33), we have

$$A_{ILL} = \frac{ab}{2}(\theta_1 - \sin 2\theta_1) + \frac{G^2}{2}(2\theta_2 - \sin 2\theta_2) \tag{34}$$

Case 4:

The filter resolution is completely inside the radar beam (see Figure 2.7) when $x_1 < \ell_1$ and $x_2 < \ell_2$. Here,

$$G_1 = h \cdot \tan\theta - x_1$$

$$G_2 = h \cdot \tan\theta + x_2 \tag{35}$$

and the illuminated area becomes

$$A_{ILL} = 2[\int_{\Psi_1}^{\Psi_2} b\sqrt{1 - (x-K)^2/a^2}\, dx + \int_{\Psi_2}^{G_2} \sqrt{G^2 - x^2}\, dx - \int_{\Psi_1}^{G_2} \sqrt{G^2 - x^2}\, dx \tag{36}$$

2.6 Effective Antenna Beamwidth

The effective beamwidths for the two-way antenna pattern is used in calculating the illuminated area. If the sidelobe levels are considered low enough to be neglected then the one-way antenna pattern may be fit with a Gaussian function, $G_S(\theta)$, and

$$G_S(\theta) = G_o \cdot \exp(-\theta^2/2\theta_o^2) \tag{37}$$

where:

G_o = gain of the antenna
θ = angle off axis
θ_o = constant.

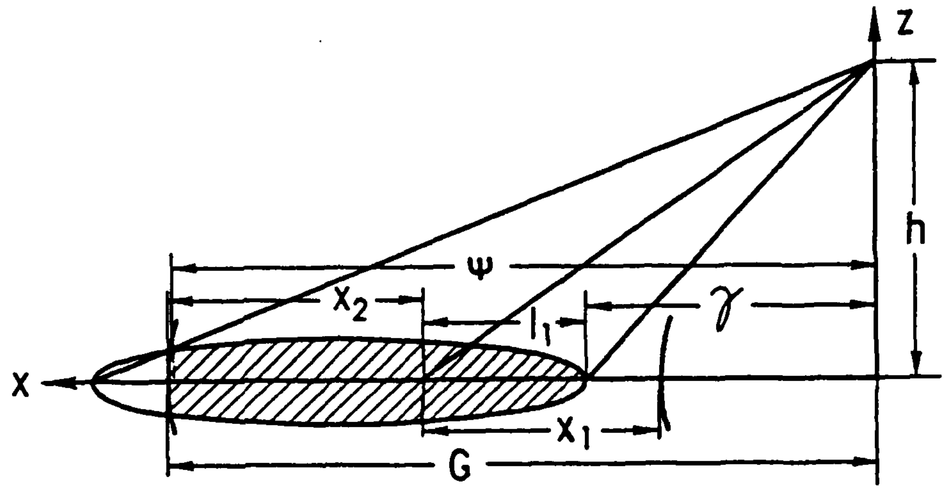

Figure 2.6: Shows Filter Partially Covering Radar Beam Resolution (Case III)

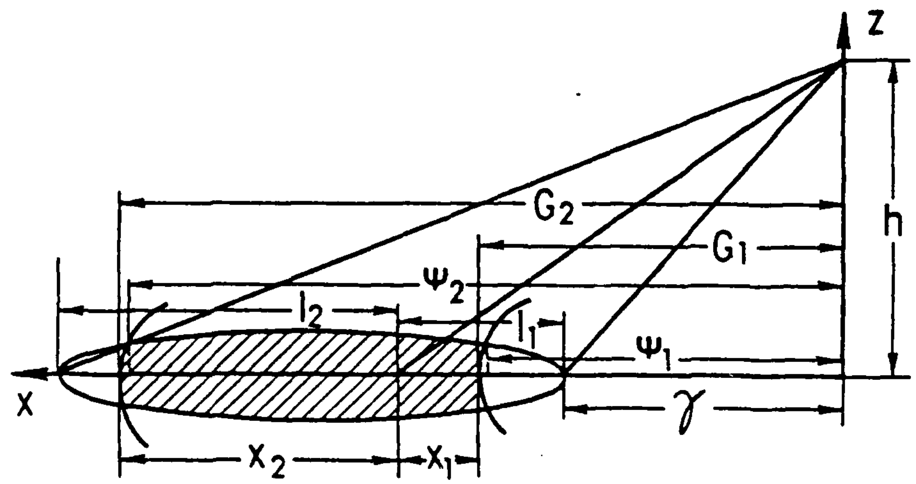

Figure 2.7: Shows Filter Contained in Radar Beam Resolution (Case IV)

Since at the half-power points, $\theta = \beta/2$, the gain is one-half G_o, the Gaussian antenna pattern requires only a knowledge of β and can be expressed as

$$G_S(\theta) = G_0 \cdot \exp(-4 \cdot \ln 2 \cdot \theta^2/\beta^2) \tag{38}$$

If two antennas with power patterns $G_1(\theta)$ and $G_2(\theta)$ are used for transmission and reception, the product pattern may be expressed as

$$G_{12}(\theta) = G_1 G_2 \cdot \exp[(-4 \cdot \ln 2)(\theta^2/\beta_1{}^2 + \theta^2/\beta_2{}^2)] \tag{39}$$

The gain will be reduced to one-half G_1G_2 when $\theta = \beta_{12}/2$, therefore

$$\beta_{12} = \sqrt{\beta_1{}^2\beta_2{}^2/(\beta_1{}^2 + \beta_2{}^2)} \tag{40}$$

If the same antenna is used for transmission and reception, then $\beta = \beta_1 = \beta_2$ and

$$\beta_{12} = \beta/\sqrt{2} \tag{41}$$

In making the calculation of illuminated area it is assumed that all the power in the antenna pattern is concentrated into a cone with a gain of G_o and a beamwidth of β_{EFF}. The effective beamwidth, β_{EFF}, can be obtained for any antenna pattern by integrating the volume and then dividing this volume by the maximum gain. Therefore,

$$\int_o^{2\pi}\int_o^{\pi} G(\theta)\sin\theta \, d\theta d\phi \triangleq \int_o^{2\pi}\int_o^{(\frac{\beta_{EFF}}{2})} G_0 \sin\theta \, d\theta d\phi \tag{42}$$

which reduces to

$$\int_o^{\pi} \exp(-4 \cdot \ln 2 \cdot \theta^2/\beta_{12}{}^2) \sin\theta \, d\theta \triangleq \int_o^{(\frac{\beta_{EFF}}{2})} \sin\theta \, d\theta$$

$$= 1 - \cos(\beta_{EFF}/2) \tag{43}$$

or

$$\begin{aligned} \beta_{EFF} &= 2\cos^{-1}(1 - \textstyle\int_o^{\pi} \exp(14 \cdot \ln 2 \cdot \theta^2/\beta_{12}{}^2) \cdot \sin\theta \, d\theta \\ &\approx 1.201\beta_{12} \end{aligned} \tag{44}$$

3.0 GENERAL DESCRIPTION

The radar may be divided into five sub-systems: (1) the power and IF processing module (PIPM), which consists of a DC/AC converter, DC power supplies, IF signal-processing circuitry, and the tuning signal generators; (2) the data acquisition module (DAM), which houses a microprocessor, an A/D converter, a rapidly responding RMS detector, a frequency counter, an averaging RMS detector, a digital altitude display and a digital cassette recorder, and the external RF module (RFM), which houses the microwave componentry; (3) the wide-band parabolic dish antennae; (4) the antenna support structure and actuator; and (5) the radar altimeter. Each of these sub-systems is described in more detail. Descriptions of their functions or operation is in the main body of this report, whereas circuit board layouts, test procedures, and wiring diagrams are located in the appendix.

3.1 Description of the Interior Equipment Package

3.1.1 Inverter/Actuator Module

This module consists of a Flitetronics static inverter and actuator control circuitry. The static inverter converts the aircraft +28 V DC to 115 V AC at 400 Hz. An actuator controls the antenna look angle and requires +12 V DC for its operation. A dedicated series regulator is used for the DC-AC conversion. Dual relays allow directional control of the actuator.

3.1.2 DC Power Module

DC voltages are required for system operation. Series regulators convert the +28 V to +18, +15, +12. Three terminal regulators convert the -18 V to -15, -12, and -5. The -18 V and -5 V are obtained using AC-DC converters.

3.1.3 FM/IF Module

This module includes the electronic circuitry which produces the tuning signals which modulate the RF oscillators, circuitry which track target returns, and IF processing circuitry. Switches which select the mode of operation of the radar are also located here.

3.1.3.1 Oscillator Tuning Signal Generator

The external RF module contains two Yig-tuned oscillators which can cover the frequency bands from 4-18 GHz. These oscillators are frequency-modulated using a triangular waveform obtained from a waveform generator whose frequency can be voltage controlled. The triangle waveform and the output from a digital-

to-analog converter are summed together to drive the oscillators to a given frequency and then sweep about this frequency. This center frequency may be manually set using a rotary switch located on the front panel of the data acquisition module or automatically set by the microprocessor.

3.1.3.2 Range-Tracker

The circuitry used to track the target returns, range tracker, is in its second generation. The original used in the TRAMAS system is described in RSL TM 331-19 [4]. Since the intermediate frequency coming out of the mixer is directly proportional both to the sweep rate and to the time delay associated with the range to the target, a range-tracker can keep the centroid of the IF response at a desired frequency by detecting the signal centroid and controlling the sweep rate. This is done by taking the range-tracker output voltage to the frequency control port of the triangle generator. A detailed discussion is included in Appendix F.

3.1.3.3 IF Processor

The mixer IF output is routed through a 35 kHz high-pass filter, an impedance transformer, an IF amplifier, and then a 50 kHz bandpass filter. The processed signal is then detected by an averaging true rms voltmeter which is sampled every 0.5 second and by a fast rms voltmeter which is sampled every 0.5 second. The bandpass-filter output is also used in locating the frequency centroid of the target return which is required by the range tracker.

3.1.3.4 Radar-Mode and Sweep-Rate Control Circuitry

This module provides most of the control switches for the various modes of operation and also the miscellaneous circuits for these purposes.

3.1.3.4.1 Radar Mode

A 2-deck, 5-position rotary switch provides the control voltages to set the radar into one of 4 modes of operation. The modes of operation are: delay-line calibration and VV, HH and VH antenna polarizations. The RF switches which are set by these control voltages are located in the external RF module. A description of these 4 operating modes is found in Section 3.3.

3.1.3.4.2 Oscillator Tuning Voltage Sweep Rate

The sweep rate of the oscillator tuning voltage may be controlled using the manual FM adjust located on this module. If the range-tracker is used, the sweep rate is adjusted via the range tracker. A reset to a selected sweep rate is provided in the tracking circuitry. This frequency is set by using the "track FM adjustment."

3.1.3.4.3 Sweep Width Select

A three-position slide switch located on the front panel of this module is used to select the width of the RF frequency sweep. For scatterometry the switch is set in the RO position. The other two positions are for use when probing with radar. They increase the bandwidth over which the oscillators sweep.

3.2 Description of the Data Acquisition Module

In this module the processed target power returns are displayed and detected. The helicopter altitude and the sweep rate are also displayed. The RF center frequency select switch, the site encoder, the digital cassette recorder, and the computer reset are located on the front panel of the module. Housed inside the module is the Intel 8080-based microcomputer.

3.2.1 Fast RMS Detector

The mean square of a signal is obtained by squaring and averaging the squared instantaneous value over the sampling interval. The root-mean-square is obtained by taking the square root of the mean-square value. Commercial true root-mean-square detectors typically employ a square law detector and an RC or op-amp integrator to obtain the average value. These instruments have settling times greater than 1 sec, making them unsuitable for fast data acquisition. A fast-rms detector based on two standard settling times of less than 25 m/s was developed to allow data collection at 0.1 sec intervals. Errors are less than 1% to 2% in the final readings for input signals in the expected input range from 0.25 mV to 1.5 V. The outputs from each of the two rms modules are supplied to an A/D converter also located in the module. Channel 1 of the fast rms detector is valid for signals from 0.25 mV to 25 mV, while Channel 2 is valid for signals from 25 mV to 1.5 V.

3.2.2 A/D Converter

A miniature modular data acquisition system is used to convert the analog input signals into the output data which is buffered three-state for interfacing with the microcomputer. Two channels of fast true-rms, the altitude and the site encoder are read. The fastest read rate is 50 kHz, the resolution is 12 bits, and the pin-programmed input range is 0 to +5 V.

3.2.3 Microcomputer System

The Intel SBC-80/10 is a complete single-board computer system. The CPU, system clock, read/write memory, nonvolatile read-only memory, I/O ports and drivers, serial communications interface, bus logic and drivers all reside on the board. The central processor is the 8080A which contains 6 8-bit general purpose

registers and an accumulator. The board contains 1K of random-access-memory and 4K of read-only memory. There are 48 programmable parallel I/O lines. The memory and I/O capabilities were expanded by an additional 4K of random-access-memory, 8K of read-only-memory and 48 parallel I/O lines by adding the SBC-104 memory expansion board.

During data acquisition, the contents of the microcomputer memory are sent to a digital cassette recorder for permanent storage. The recorder interfaces to the CPU via one of the bi-directional parallel ports. It is controlled by software and provides its own error checking during read and write operations. The data is recorded using phase shift keying at a recording density of 800 bits per inch. With stándard digital cassette tapes this allows over 150 minutes of data to be recorded per cassette side.

The operator interfaces with the computer using a hand-held pocket terminal. It is capable of generating and transmitting all 128 ASCII codes. The codes are sent to the microcomputer as an 8-bit serial stream. A display section consists of 8 "starburst" LED display characters received from the processor. The terminal contains an internal 30 character buffer which can be displayed by moving the 8 LED "window" across it. Whenever possible, I/O was limited to fewer than 8 characters so that the window did not have to be moved.

The microcomputer software was written to acquire a real time data stream by sampling the various instruments, allow the writing of text records onto the cassette tape, allow the dumping of the recorded data into various formats, allow computer control of the RF frequency, provide a test loop to determine if all devices are being read properly by the computer, allow operator control of the digital cassette recorder, and provide time tags based on the computer's real time clock.

3.3 RF Module and Antennae

The RF oscillators and the microwave components of the radar are housed in this module. This module is located directly behind the 24-inch dish antenna. Rigid coax links the module to the feeds of the antennae and multiconductor and flexible coax cables link the module to the FM/IF module.

Two antennae are required by this radar which operates in four modes. Three of the modes control the antenna polarizations for transmission and reception. For HH-polarization, only the 24-inch dish is used; for VV-polarization the 18-inch

dish is used alone; if both antennae are used, the polarization is VH. In the fourth mode the RF signal is sent via flexible coax to the open-circuited delay line located in the FM/IF module for internal calibration.

3.4 Altimeter

A Bonzer Mini-Mark radar altimeter provides accurate altitude information from 45 to 1000 feet. It is mounted to the helicopter using the cargo-hook hard points. A three-conductor cable connects the altimeter to the back panel connector of the Data Acquisition Module, where a digital panel meter is used as the indicator for the altimeter. The altimeter output also goes to the A/D converter for recording.

REFERENCES

[1] Ulaby, F.T., R.K. Moore and A.K. Fung, Microwave Remote Sensing: Active and Passive. Volume II: Radar Remote Sensing and Surface Scattering and Emission Theory, Chapter 10. Reading, Massachusetts: Addison-Wesley Publishing Company, 1982.

[2] Ulaby, F.T., R.K. Moore and A.K. Fung, Microwave Remote Sensing: Active and Passive. Volume II: Radar Remote Sensing and Surface Scattering and Emission Theory, Chapter 7. Reading, Massachusetts: Addison-Wesley Publishing Company, 1982.

[3] Batlivala, P. and H. Khamsi, "Calculation of Area for FM-CW Radar," Remote Sensing Laboratory Technical Memorandum 177-41, University of Kansas Center for Research, Inc., Lawrence, Kansas, 1973.

[4] Milberger, S., "Technical Description of Radar Range Tracker in the TRAMAS," Remote Sensing Laboratory Technical Memorandum 331-19, University of Kansas Center for Research, Inc., Lawrence, Kansas, 1980.

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APPENDIX A

SPECIFICATIONS

A1 INVERTER/ACTUATOR MODULE

A1.1 400 Hz STATIC INVERTER

Input Voltage:	28 VDC ± 2.0 VDC
Input Current:	31 A Full Load and 1 A No Load
Output Voltage:	115 VAC and 26 VAC
Power Output:	600 VA Continuous
Protection:	88 V Transients on 28 V Line for 1 ms
Efficiency:	70% at Full Load
Temperature:	-55° C to 70° C
Weight:	14.6 lbs.
Size:	8-1/2" W x 12" L x 4-1/16" H

Pins	Description
A	Output: 26 VAC
B	Output: 115 VAC
C	Output: Common AC return
D	Input: + 28 VDC
E	NC
F	Chassis Ground Input DC Return
G	NC
H	NC
J	Oscillator Sync.

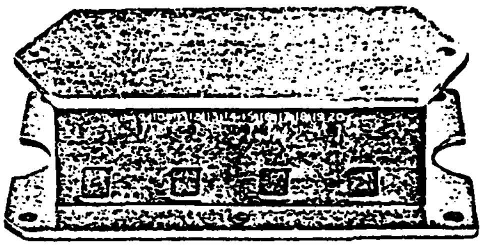
A1.2 12 VDC ACTUATOR

Manufacturer:	Saginaw
Part Number:	5703605
Rated Load:	750 lbs.
Current Draw:	22 A max
Stroke	4 inches
Travel Rate:	1.1 in /sec

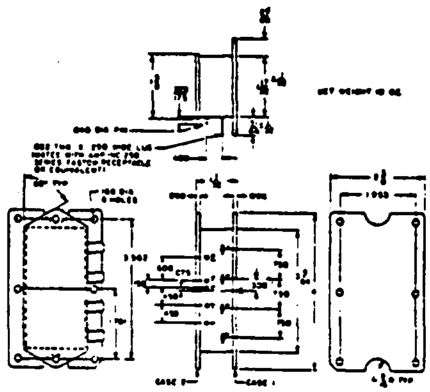
A1.3 VOLTAGE REGULATOR

DESCRIPTION

The LAS 7200 Series of Power Hybrid Voltage Regulators is designed for applications requiring a well regulated output voltage for load current variations up to 30 amperes. A key feature of the LAS series of Power Hybrid Voltage Regulators is its construction. A high degree of thermal isolation between the heat generating power elements and the heat sensitive control and reference elements is achieved by the placing of the power section on the heat-dissipating base of the unit, and the control stage on the heat-dissipating upper surface. This thermal isolation results in extremely low thermal drift characteristics for changes in power levels.



OUTLINE DRAWING



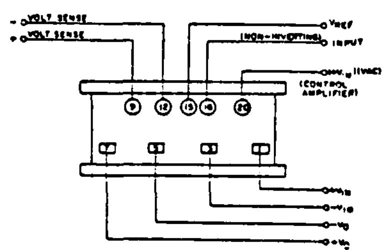
OUTLINE DRAWING, POWER HYBRID VOLTAGE REGULATOR, LAS 7000 SERIES

ELECTRICAL CHARACTERISTICS

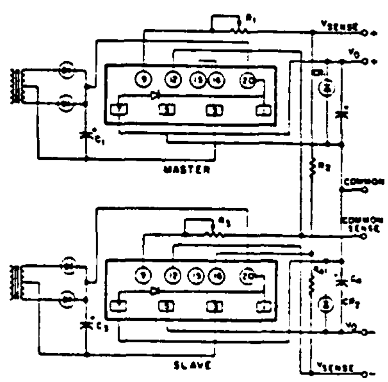
PARAMETER	SYMBOL	CONDITION	MIN.	MAX.	UNITS
Input voltage to pin (1)**	V_{in} (1)		7.25	40.0	volts
Input voltage to pin (20)**	V_{in} (20)		12.3	40.0	volts
Output voltage	V_O		4.75	29.4	volts
Input-output differential**	(V_{in} (1)-V_O)		2.5	28.6	volts
Input-output differential**	(V_{in} (20)-V_O)		7.60	28.6	volts
Output current	I_O			30.0	amps
Standby current	I_O (1)			40.0	mA
Standby current	I_O (20)			7.0	mA
Power dissipation	P_D	Plate #1 @ 25°C		400	watts
Thermal resistance junction—Case #1	θ_J-C1			0.44	°C/watt
Storage temperature	T_S		−55	+125	°C
Power transistor junction temperature	T_J			+200	°C
Regulation line*				0.016	%/ΔV_{in}
Regulation load*				0.2	%
Programming resistance				1000 nominal	ohms/volt
Programming voltage				one/one	volt/volt
Temperature coefficient				0.015	%/°C
Ripple attenuation*		V_{in} (1) minimum I_O maximum	60		dB

LAS 7000 SERIES

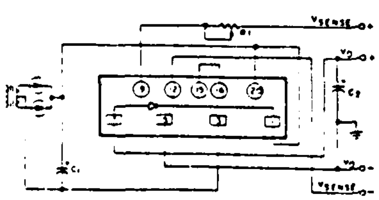
CONNECTION DIAGRAMS



9-PIN POWER HYBRID VOLTAGE REGULATOR



DUAL TRACKING POWER HYBRID VOLTAGE REGULATOR



POSITIVE POWER HYBRID VOLTAGE REGULATOR CIRCUIT

NOTES:

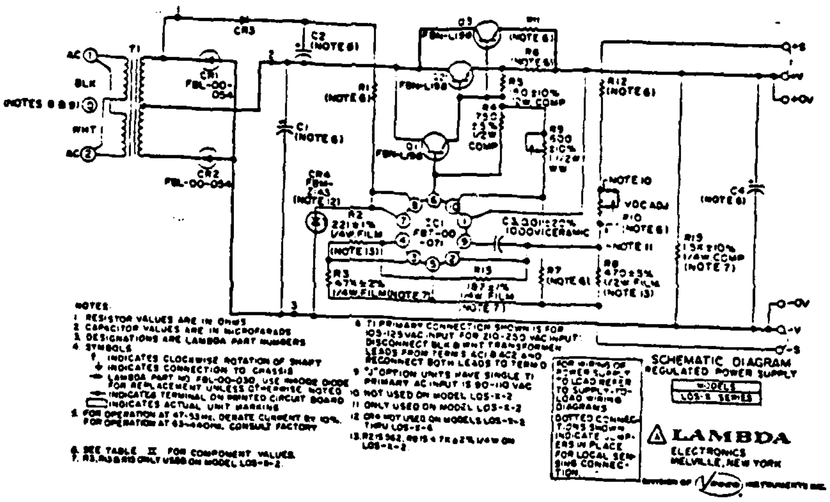
1. Minimum value of input filter capacitors C1 and C3 is determined by: C1, C3 = I_O X (2000 mfd/amp) recommended
2. Minimum value of output capacitors C2 and C4 is determined by: C2, C4 = I_O X (100 mfd/amp)
4. Minimum value of output voltage adjust resistors R1 and R3 is determined by: R1, R3 = (0.25V_O x 1000Ω/V) ohms wirewound. Use next highest standard value.
5. Values of tracking reference voltage divider resistors R2 and R4 for all models are determined by
   a) R2 = (2000V_O − 2490) ohms ± 1%, ½W film
   b) R4 = 2.49K ohms ± 1%, ½W film
6. Rectifiers CR1 and CR2 should be rated at peak inverse voltage of 50V and forward current equal at least to maximum

A2 LAMBDA DC POWER SUPPLY MODULE

Model:	LOS-χ-5	LOS-χ-20
Voltage	5 ± 5% V	20 ± 5% V
Current:	9.0 A max	3.8 A max
Regulation:	.15%	
Ripple:	1.5 mV rms	
Noise:	5 mV p-p	
Temp. Coef.:	.03% /°C	
AC Input:	105-125 VAC at 47 - 440 Hz	
Input Power:	160 Watts	
Operating Temp.:	0° C to 60° C	

Overvoltage Protectors

Model:	L-12-OV-5	L-6-OV-20
Trip Voltage:	6.6 ± .2 V	22.8 ± .7 V
Current:	12 A	6 A



Models	Schematic Components								
	C1	C2	C4	R1	R6	R7	R10	R11	R12
	-10+100% ELECT	-10+75% ELECT	-10+75% ELECT	±3%, 3W WW	±5% WW	¼W COMP	±10% 1¼W WW	±5% WW	¼W FILM
LOS-X-5	34,000 mf 15 vdc	47 mf 35 vdc	470 mf 16 vdc	200 ±5%, ¼W COMP	0.10 3W	2.2K ±5%	1.2K	0.10 3W	Jumper
LOS-X-20	12,500 mf 50 vdc	47 mf 60 vdc	220 mf 50 vdc	3.6K	0.30 2W	10K ±5%	5.0K	0.30 2W	768 ±1%

A3. FM/IF Module

A3.1 IF Amplifier

Model: HP 465A

Freq: 5 Hz to 1 MHz

Output: > 10 volts rms open circuit; > 5 volts rms into 50 ohms (+ 2 W).

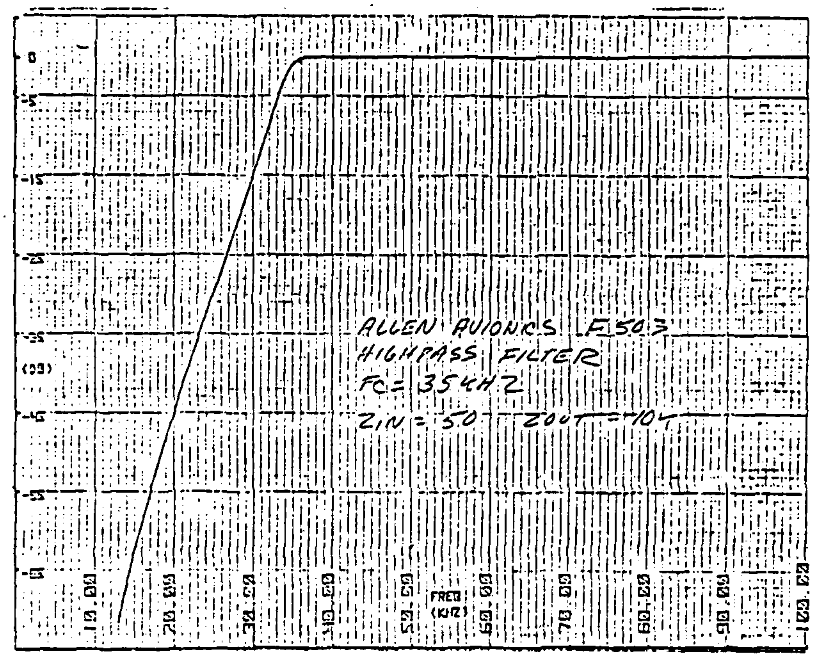
Impedance: 10 M ohm shunted by < 20 pF

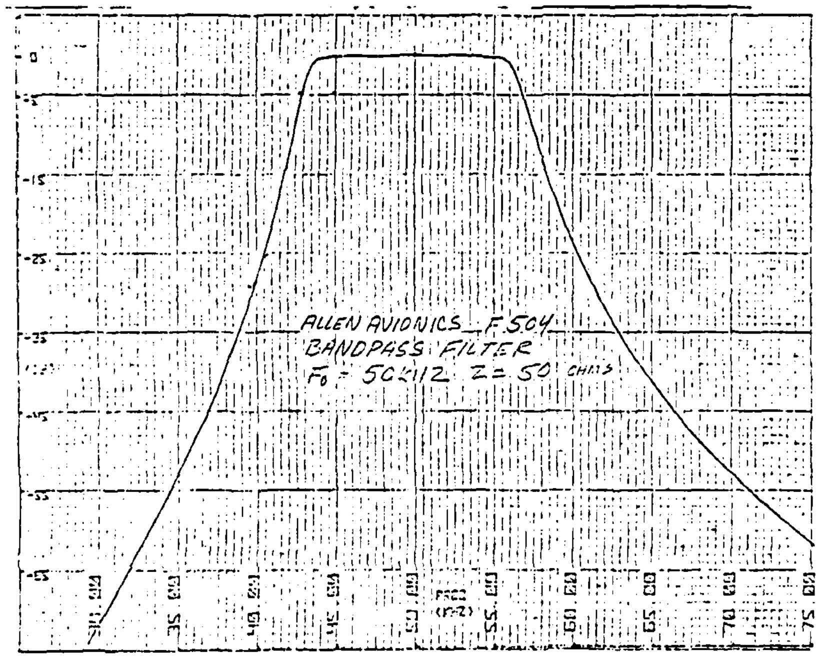
Output Impedence: 50 Ω

Power: 115 or 230 V; 50 to 400 Hz; 10 watts

A3.2 IF Filters

Manufacturer	High Pass	Band Pass
Allen Avionics	F503	F504
Cut-off frequencies (fc) 3 dB max:	35 kHz	43.4 kHz, 56.8 kHz
Impedance range	50Ω in; 10 KΩ out	50Ω in; 50Ω out
Maximum ripple	1 dB	1 dB
Maximum insertion loss	2 dB	2 dB


(DB)
FREQ (KHZ)
ALLEN AVIONICS F.503
HIGHPASS FILTER
FC = 35KHZ
ZIN = 50 ZOUT = 10K


FREQ (KHZ)
ALLEN AVIONICS F.504
BANDPASS FILTER
F_0 = 50KHZ Z = 50 OHMS

A4 DATA ACQUISITION MODULE

A4.1 DATEL MDAS-16 A/D CONVERTER

ANALOG INPUTS

Number of Channels	16 Single Ended (MDAS-16) 8 Differential (MDAS-8D)
Input Voltage Ranges	
unipolar	0 to +5V 0 to +10V
bipolar	±2.5V, ±5V, ±10V
Common Mode Range, min.	±10V
Max. Input Voltage, no damage	±15V
Input Impedance	100 megohms
Input Bias Current	3nA, 10nA max 0 to 70°C
Input Capacitance	
OFF channel	10 pF
ON channel	100pF

ACCURACY

Resolution	12 Bits
Error, max. 50kHz sampling	±.025% of FSR
Nonlinearity, max.	±½ LSB
Diff. Nonlinearity, max.	±½ LSB
Gain Error	Adj. to zero
Offset Error	Adj. to zero
Temp. Coeff. of Gain, max.	±30ppm/°C
Temp. Coeff. of Offset, max	±7ppm/°C of FS
Diff. Linearity Tempco, max.	±3ppm/°C of FS
Common Mode Rejec., min.	70 dB at 1 kHz
Monotonicity	0°C to 70°C
Power Supply Rejection	.01%/% Supply

DYNAMIC CHARACTERISTICS

Throughput Rate, max	50 kHz
Acquisition Time	6 µsec.
Conversion Time	14 µsec.
Aperture Time, max	100 nsec.
Sample-Hold Droop, max	200 µV/msec.
Feedthrough, max	.01%
Channel Crosstalk (Mux.)	80 dB at 1 kHz

DIGITAL OUTPUTS

Parallel Data Out	12 parallel lines of buffered tri-state output data Drives 12 TTL loads
Coding	Straight binary, offset binary, and two's complement
Serial Out	Output data in MSB first NRZ format. Straight binary and offset binary coding Drives 5 TTL loads
Mux Address Out	Buffered output of address register Drives 20 TTL loads
Delay Out	Drives 5 TTL loads
Clock Out	Drives 5 TTL loads
$\overline{EOC}$ (Status)	Drives 4 TTL loads
MSB Out	Drives 5 TTL loads
$\overline{MSB}$ Out	Drives 5 TTL loads

DIGITAL INPUTS

$\overline{Enable}$	Three separate inputs which enable tri-state outputs in 4 bit bytes 1 TTL load
Mux Address In	3 bit (MDAS-8D) or 4 bit (MDAS-16) binary address 1 LS TTL load
$\overline{Strobe}$	1 LS TTL load with 10K pull up resistor
A/D Trigger	1 LS TTL load with 10K pull-up resistor
A/D $\overline{Trigger}$	1 LS TTL Load
Mux Enable	1 TTL load with 10K pull-up resistor
Count Enable	1 LS TTL load with 10K pull-up resistor
$\overline{Load\ Enable}$	1 LS TTL load with 10K pull-up resistor
$\overline{Clear\ Enable}$	1 LS TTL load with 10K pull up resistor
MSB In	1 TTL load
Short Cycle	1 TTL load with 10K pull-up resistor

POWER REQUIREMENT

+15VDC ±0.5V @ 65mA
-15VDC ±0.5V @ 60 mA
+5VDC ±0.25V @ 200mA

PHYSICAL ENVIRONMENTAL

Operating Temp. Range	0°C to 70°C
Storage Temperature Range	-25°C to +85°C
Package Size	4.6 × 2.5 × 0.375 inches (116.8 × 63.5 × 9.5 mm)
Package Type	Steel, shielded on 5 sides
Weight	6 oz. (170 g)

NOTES: 1. All outputs are Vout ("0") ≤ +0.4V, Vout ("1") ≥ +2.4V
2. All inputs are Vin ("0") ≤ +0.8V, Vin ("1") ≥ +2.0V

ORDERING INFORMATION

Price	(1-9)	(100's)
MDAS-16	$295.00	$195.00
MDAS-8D	$295.00	$195.00

These modules are also available in extended temperature range versions designated with the suffix EX (-25°C to +85°C) or EXX-HS (-55°C to 85°C) with hermetically sealed semiconductor components. Contact factory for price and delivery.

Included with each module is a mating right-angle 72 pin connector (AMP 3-86063-2). Additional connectors may also be ordered by the following number: 58-2082010 Connector $10.00 each.

Trimming Potentiometers: TP 20K $3.00 each

Multiplexer expander modules are also available. The MDXP 32 adds 32 single ended or 16 differential channels with control logic. Price is $199.00. The MDXP 32-1 is identical but without control logic. Price is $179.00

PIN CONNECTIONS for MDAS-16

	Top	Bottom	
+15VDC	1T	1B	-15VDC
Analog Gnd	2T	2B	Analog Gnd
Ch 0 In	3T	3B	Ch 8 In
Ch 1 In	4T	4B	Ch 9 In
Ch 2 In	5T	5B	Ch 10 In
Ch 3 In	6T	6B	Ch 11 In
Ch 4 In	7T	7B	Ch 12 In
Ch 5 In	8T	8B	Ch 13 In
Ch 6 In	9T	9B	Ch 14 In
Ch 7 In	10T	10B	Ch 15 In
Amplifier In Hi	11T	11B	Amplifier In Lo
Range 1 Select	12T	12B	Range 2 Select
Sample Hold Out	13T	13B	Amplifier Out
Enable (Bits 1-4 Out)	14T	14B	Sum Junc (Bipolar Off)
Bipolar Offset	15T	15B	Enable (Bits 5-8 Out)
Ext Offset Adjust	16T	16B	Ext Gain Adjust
Enable (Bits 9-12)	17T	17B	Mux Enable
Serial Out	18T	18B	Count Enable
8 Out Mux	19T	19B	8 In Mux
4 Out Address	20T	20B	4 In Address
2 Out Lines	21T	21B	2 In Lines
1 Out	22T	22B	1 In
Delay Out	23T	23B	MSB Out (TTL)
MSB In (TTL)	24T	24B	$\overline{Load\ Enable}$
Strobe	25T	25B	$\overline{Clear\ Enable}$
A/D Trigger	26T	26B	Clock Out
A/D Trigger	27T	27B	EOC (status)
Short Cycle	28T	28B	$\overline{MSB}$ Out (TTL)
Bit 1 Out* (MSB)	29T	29B	Bit 2 Out*
Bit 3 Out*	30T	30B	Bit 4 Out*
Bit 5 Out*	31T	31B	Bit 6 Out*
Bit 7 Out*	32T	32B	Bit 8 Out*
Bit 9 Out*	33T	33B	Bit 10 Out*
Bit 11 Out*	34T	34B	Bit 12 Out* (LSB)
Digital Gnd	35T	35B	Digital Gnd
+5VDC	36T	36B	+5VDC

*Three State Outputs

PIN CONNECTIONS for MDAS-8D

	Top	Bottom	
+15VDC	1T	1B	-15VDC
Analog Gnd	2T	2B	Analog Gnd
Ch 0 Hi In	3T	3B	Ch 0 Lo In
Ch 1 Hi In	4T	4B	Ch 1 Lo In
Ch 2 Hi In	5T	5B	Ch 2 Lo In
Ch 3 Hi In	6T	6B	Ch 3 Lo In
Ch 4 Hi In	7T	7B	Ch 4 Lo In
Ch 5 Hi In	8T	8B	Ch 5 Lo In
Ch 6 Hi In	9T	9B	Ch 6 Lo In
Ch 7 Hi In	10T	10B	Ch 7 Lo In
Amplifier In Hi	11T	11B	Amplifier In Lo
Range 1 Select	12T	12B	Range 2 Select
Sample Hold Out	13T	13B	Amplifier Out
Enable (Bits 1-4 Out)	14T	14B	Sum Junc (Bipolar Off)
Bipolar Offset	15T	15B	Enable (Bits 5-8 Out)
Ext Offset Adjust	16T	16B	Ext Gain Adjust
Enable (Bits 9-12 Out)	17T	17B	Mux Enable
Serial Out	18T	18B	Count Enable
8 Out Mux	19T	19B	8 In Mux
4 Out Address	20T	20B	4 In Address
2 Out Lines	21T	21B	2 In Lines
1 Out	22T	22B	1 In
Delay Out	23T	23B	MSB Out (TTL)
MSB In (TTL)	24T	24B	$\overline{Load\ Enable}$
Strobe	25T	25B	$\overline{Clear\ Enable}$
A/D Trigger	26T	26B	Clock Out
A/D Trigger	27T	27B	$\overline{EOC}$ (status)
Short Cycle	28T	28B	$\overline{MSB}$ Out (TTL)
Bit 1 Out* (MSB)	29T	29B	Bit 2 Out*
Bit 3 Out*	30T	30B	Bit 4 Out*
Bit 5 Out*	31T	31B	Bit 6 Out*
Bit 7 Out*	32T	32B	Bit 8 Out*
Bit 9 Out*	33T	33B	Bit 10 Out*
Bit 11 Out*	34T	34B	Bit 12 Out* (LSB)
Digital Gnd	35T	35B	Digital Gnd
+5VDC	36T	36B	+5VDC

*Three State Outputs

A4.2 Microcomputer

SBC-80/10 SPECIFICATIONS

DC POWER REQUIREMENTS

The DC power requirements are given in the table below.

	1	2
V_{CC} = +5V ± 5%	I_{CC} = 4.0A max.	I_{CC} = 2.9A
V_{DD} = +12V ± 5%	I_{DD} = 0.40A max.	I_{DD} = 140mA
V_{BB} = -5V ± 5%	I_{BB} = 0.20A max	I_{BB} = 2mA
V_{AA} = -12V ± 5%	I_{AA} = 0.175 max.	I_{AA} = 175mA

Notes: 1 The values assume that four 8708 PROM's are present and that ten optional 220/330 Ω termination networks being driven low have been installed in the Parallel I/O Interface.

2 These values assume that the 8708 PROM's and optional termination networks are not present.

* Present system includes one 2708 EPROM and no optional terminating; therefore the power requirement would be close to case 2 above.

ENVIRONMENT

Temperature extremes can cause instability, or result in permanent damage to the circuits on the module. Ambient temperature must, therefore, be maintained within the limits of 0° C to 55° C. Exercise caution in locating the module, giving particular attention to radiant and conducive sources of heat. Remember that the module itself, when installed, will contribute some heat to the environment. Maintain an adequate clearance to permit the convective dissipation of heat from the elements on the card.

Relative humidity should not exceed 90%, non-condensing.

SPECIFICATIONS

MEMORY ADDRESSING

ROM/EPROM:

4K or 8K segments starting at any jumper-selectable base address on a 4K byte boundary. Refer to paragraph 2-10 for further details.

Note: All EPROM/ROM addresses must reside in the range of 0000_H to $7FFF_H$ or 8000_H to $FFFF_H$.

RAM:

4K, 8K, or 16K segments starting at any jumper-selectable base address on a 4K byte boundary. Certain addresses are disallowed for the 108/116 modules. Refer to paragraph 2-9 for further details.

Note: Base addresses 7000_H and $F000_H$ not allowed for SBC 108. Base addresses 5000_H – 7000_H and $D000_H$ – $F000_H$ not allowed for SBC 116.

MEMORY RESPONSE TIME

Memory	Access (ns)	Cycle (ns)
RAM	575 max*	675 max*
EPROM/ROM	455 max	685 max

*Without Refresh Interruption

I/O ADDRESSING

Port	1	2	3	4	5	6	8255 No. 1 Control	8255 No. 2 Control	USART Data	USART Control
Address	X4	X5	X6	X8	X9	XA	X7	XB	XC	XD

Note: X is any hex digit assigned by jumper selection.

I/O TRANSFER RATE

Parallel: Read or Write cycle time 760 ns max
Serial: (USART)

Frequency (kHz) (Jumper Selectable)	Baud Rate (Hz) Synchronous	Baud Rate (Hz) Asynchronous (Program Selectable) ÷ 16	÷ 64
153.6	—	9600	2400
76.8	—	4800	1200
38.4	38400	2400	600
19.2	19200	1200	300
9.6	9600	600	150
4.8	4800	300	75
6.98	6980	—	110

SERIAL COMMUNICATIONS CHARACTERISTICS

Synchronous
- 5–8 bit characters
- Internal or external character synchronization
- Automatic Sync Insertion

Asynchronous
- 5–8 bit characters
- Break characters generation
- 1, 1½, or 2 stop bits
- False start bit detectors

INTERRUPTS

Eight interrupt request lines may originate from the Programmable Peripheral Interface (4 lines), the USART (2 lines) or user specified devices via the I/O edge connector (2 lines) or Interval Timer.

INTERRUPT REGISTER ADDRESSES

Interrupt Mask Register	X1
Interrupt Status Register	X0

Note: X is any hex digit assigned by jumper selection.

TIMER INTERVAL

1.003 ms ±0.1% when 110 Baud Rate is selected
1.042 ms ±0.1% for all other Baud Rates

INTERFACES

Bus	All signals TTL compatible
Parallel I/O	All signals TTL compatible
Serial I/O	RS232C
Interrupt Requests	All TTL compatible

CONNECTORS

Interface	No. of Pins	Centers (in.)	Mating Connectors
Bus	86	0.156	CDC VPB01E43A00A1
Parallel I/O	50	0.1	3M 3415-000 or TI H312125
Serial I/O	26	0.1	3M 3462-000 or TI H312113
Aux Power	60	0.1	AMP PE5-14559 or TI H311130

Note: Connector heights and wire-wrap pin lengths are not guaranteed to conform to Intel OEM packaging.

PHYSICAL CHARACTERISTICS

Width: 12.00 in. (30.48 cm) Depth: 0.50 in. (1.27 cm)
Height: 6.75 in. (17.15 cm) Weight: 14 oz (397.3 gm)

ELECTRICAL CHARACTERISTICS[1]

Average DC Current

	without EPROM[2]	with 8708 EPROM[3]	with 2716 EPROM[4]	RAM[5]
V_{CC} = +5V ±5%	I_{CC} = 2.85A max	3.6A max	4.0A max	600 mA max
V_{DD} = +12V ±5%	I_{DD} = 450 mA max	700 mA max	450 mA max	400 mA max
V_{BB} = -5V ±5%	I_{BB} = 3 mA max	180 mA max	3 mA max	3 mA max
V_{AA} = -12V ±5%	I_{AA} = 60 mA max	60 mA max	60 mA max	not used

Notes:
1. All current values given here include RAM power.
2. Does not include power required for optional EPROM, I/O drivers, and I/O terminators.
3. With four 8708 EPROMs and eight 220Ω/330Ω input terminators installed, all terminator inputs low.
4. With four Intel® 2716 EPROMs and eight 220Ω/330Ω input terminators installed, all terminator inputs low.
5. RAM chips and RAM control logic (powered via Auxiliary Power Bus).

AUXILIARY POWER

An Auxiliary Power Bus is provided to allow separate power to RAM for systems requiring battery backup of read/write memory. Selection of this Auxiliary RAM Power Bus is made via jumpers on the board.

MEMORY PROTECT

An active-low TTL compatible MEMORY PROTECT signal is brought out on the Auxiliary connector which, when asserted, disables Read/Write access to RAM memory on the board. This input is provided for the protection of RAM contents during system power-down sequences.

LINE DRIVERS AND TERMINATORS

I/O Drivers

The following line drivers and terminators are all compatible with the I/O driver sockets on the SBC 104/108/116.

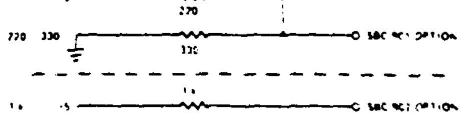
Driver	Characteristic	Sink Current (mA)	Driver	Characteristic	Sink Current (mA)
7438	I, OC	48	7409	NI, OC	16
7437	I	48	7408	NI	16
7432	NI	16	7403	I, OC	16
7426	I, OC	16	7400	I	16

Note: I = inverting, NI = non-inverting, OC = open collector

Ports 1 and 4 have 25 mA totem-pole drivers and 1 kΩ terminators.

I/O Terminators

Terminators: 220Ω/330Ω divider or 1 kΩ pull up



Bus Drivers

Function	Characteristic	Sink Current (mA)
Data	Tri-State	50
Commands	Tri-State	25

ENVIRONMENTAL

Operating Temperature: 0°C to +55°C

A4.3 RMS VOLTMETERS

(a) Boonton

The Boonton has "AUTORANGING" capability; i.e., it automatically selects correct range for the voltage applied to the input connector (within the voltage and frequency limits).

Range:	300 V to 300 mV; +50 dBm to -70 dBm
Bandwidth:	10 Hz to 20 MHz; 10 Hz to 100 kHz
dBm accuracy (range= +50 - -60 dBm):	(50 Hz to 100 kHz) = .2 dB
Stability:	115 V ± 10%; 50 Hz to 400 Hz; 2 min warmup; 0° to 50° C
Response:	Crest Factor -6 at full scale; Waveform - complex + random
Response Time:	Fast - 1 to 2 secs; Slow - 4 to 6 secs

(b) Analog Devices TRMS-to-DC Converter (442J)

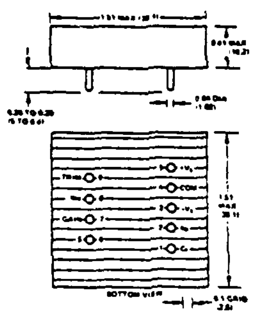
MODEL	442J	442K	442L
TRANSFER EQUATION	$E_O = \sqrt{\overline{E_{IN}^2}}$	*	*
ACCURACY[1]			
Total Error, Sinewave Input, f ≤ 20kHz			
No External Adjustment			
Input Range 0 to $2V_{rms}$	±2mV ±0.15% of Rdg., max	*	*
External Adjustment			
Input Range 0 to $2V_{rms}$[2]	±1mV ±0.05% of Rdg., max	*	*
$10mV_{rms}$ to $2V_{rms}$[3]	±0.5mV ±0.05% of Rdg., max	*	*
Additional Error, Sinewave Input 20kHz ≤ f ≤ 500kHz			
With or Without External Adjustment			
For Any Input Range	(±25μV ±0.0025% of Rdg.) × $\left(\frac{f(kHz) - 20kHz}{1kHz}\right)$ max	*	*
vs. Temperature (0 to +70°C), max	±100μV/°C plus ±0.01% of Rdg./°C	±50μV/°C plus ±0.01% of Rdg./°C	±35μV/°C plus ±0.01% of Rdg./°C
vs. Supply Voltage	±0.1mV/%	*	*
Warm-Up Time	5 minutes	*	*
FREQUENCY RESPONSE, SINEWAVE INPUT			
±1% Reading Error[3]			
Input $3V_{rms}$	300kHz	*	*
$2V_{rms}$	700kHz	*	*
$1V_{rms}$	800kHz	*	*
$0.2V_{rms}$	120kHz	*	*
$0.1V_{rms}$	80kHz	*	*
$0.01V_{rms}$	25kHz	*	*
-3dB Reading Error			
Input $3V_{rms}$	5MHz	*	*
$2V_{rms}$	8MHz	*	*
$1V_{rms}$	7MHz	*	*
$0.2V_{rms}$	3MHz	*	*
$0.1V_{rms}$	2MHz	*	*
$0.01V_{rms}$	300kHz	*	*
Internal Filter Time Constant	1.5ms	*	*
External Filter Time Constant[4]	15ms/μF	*	*
Total Averaging Time Constant[4]	1.5ms + 15ms/μF	*	*
CREST FACTOR			
±0.2% Additional Reading Error	7	*	*
±0.5% Additional Reading Error	10	*	*
INPUT SPECIFICATIONS			
Voltage			
Signal Range	$±10V_{peak}$ min	*	*
Safe Input	$±V_s$	*	*
Impedance	7.5kΩ ±10%	*	*
OUTPUT SPECIFICATIONS[5]			
Rated Output			
Voltage	+10.0V min	*	*
Current	+5mA min	*	*
Impedance	0.1Ω	*	*
Offset Voltage @ +25°C	±2mV max	*	*
With External 20kΩ Trim Pot	Adjustable to Zero	*	*
POWER SUPPLY[6]			
Voltage, Rated Specifications	±15V dc	*	*
Voltage, Operating	±(6 to 18)V dc	*	*
Current, Quiescent	±12mA	*	*
TEMPERATURE RANGE			
Rated Performance	0 to +70°C	*	*
Operating	-25°C to +85°C	*	*
Storage	-55°C to +125°C	*	*
CASE SIZE	[illegible]	*	*
PRICE			
(1-9)	$98	$124	$140
(10-24)	$91	$115	[illegible]

*Specifications same as model 442J.
[1] Error is specified as the sum of two components: a fixed term plus a percentage of output signal (reading). Refer to TOTAL ACCURACY, page 3.
[2] Refer to OPTIONAL AC CALIBRATION PROCEDURE, page 3.
[3] Refer to AC CALIBRATION PROCEDURE, page 3.
[4] Connect optional filter capacitor between pin 1 and pin 2 (see Figure 2). Pin 1 is protected for shorts to ground and the positive supply voltage. Pin 1 is not protected for negative voltage greater than 1 volt.
[5] Protected for short circuit to ground and/or either supply voltage.
[6] Recommended power supply: Analog Devices model 904 [illegible].

Specifications subject to change without notice.

OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).



Weight: 40 grams

MATING SOCKET AC1016
PRICE (1-9) $5.00

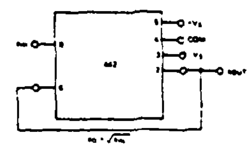


Figure 1. Wiring Connections for RMS Measurements (No External Trim)

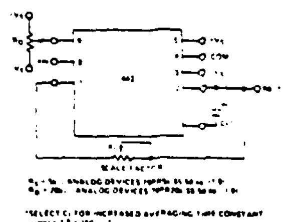


Figure 2. Optional External Adjustment for RMS Measurements

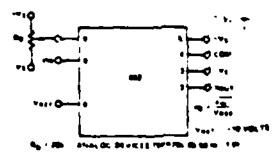
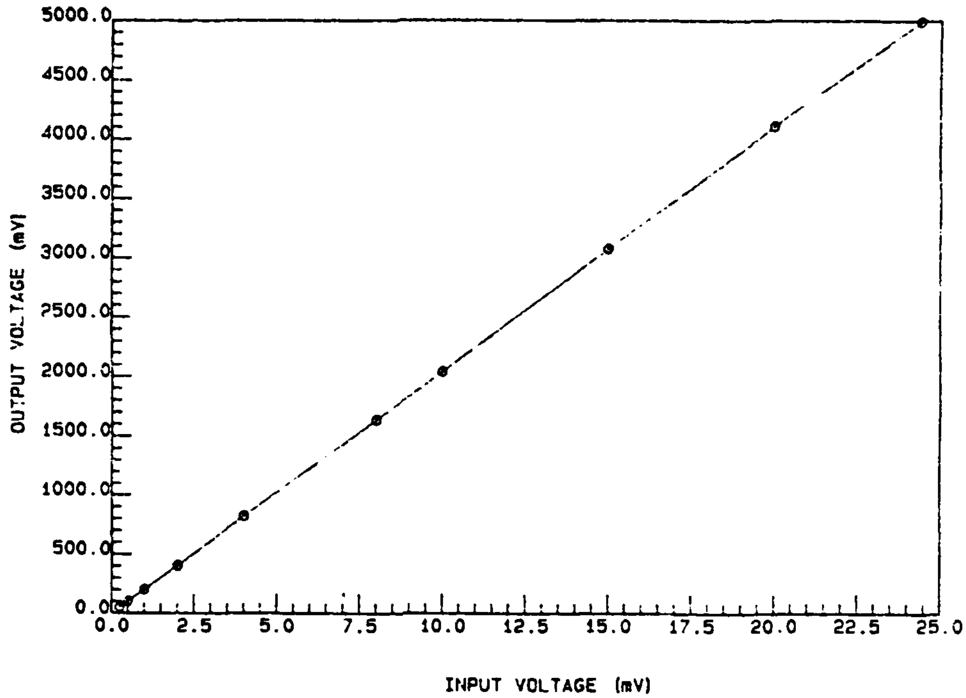
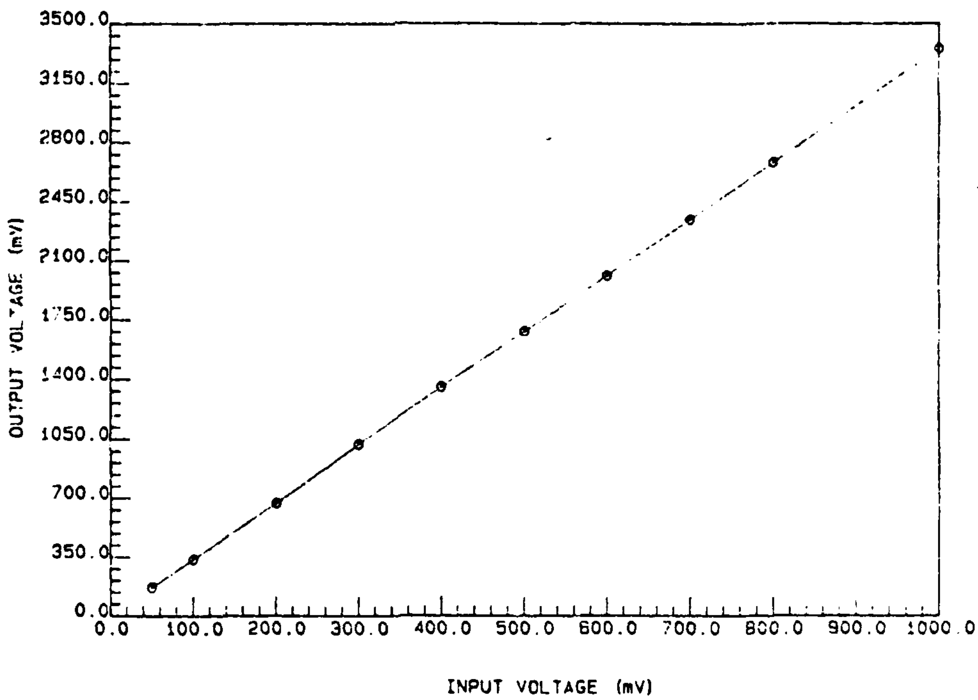


Figure 3. Wiring Connections for Mean Square Measurements with Adjustable Scale Factor (V_REF)

(c) I/O Characteristics of True RMS Board



INPUT vs OUTPUT VOLTAGE FOR CHANNEL 1 AT 50 kHz



INPUT vs OUTPUT VOLTAGE FOR CHANNEL 2 AT 50 kHz

A4.4 FLUKE FREQUENCY COUNTER

OPERATING RANGES

Frequency:
5 Hz to 80 MHz

Period:
5 Hz to 1 MHz single and multiple period averages

Totalize:
1 count to 999999 counts

INPUT CHARACTERISTICS

Sensitivity:
25 mV, typically 15 mV rms sine wave, 5 Hz to 80 MHz
Frequency and totalize: 200 mV P-P pulse amplitude with minimum pulse width of 20 nsec. Duty cycle > 10%.
Period: 200 mV P-P pulse amplitude with minimum pulse width of 200 nsec. Duty cycle > 10%.

Impedance:
1 MΩ shunted by less than 30 pf for signal levels < 500 mV decreasing to approx. 220K shunted by less than 40 pf for levels greater than 500 mV.

Filter:
1 MHz (3dB point) lowpass

Attenuator:
Decreases sensitivity by 10

Overload:
250V rms 5 Hz to 1 kHz decreasing to 20V at 80 MHz

RESOLUTION

Frequency:
Four manually selected gate times of:

- 10ms (100 Hz resolution)
- 100ms (10 Hz resolution)
- 1s (1 Hz resolution)
- 10s (0.1 Hz resolution)

Autorange position will automatically seek to fill all 6 digits but will not select a gate time greater than 1 second (1 Hz resolution)

Period:
Manual selection of single period through 10^3 periods averaged ratios:

- 10^0 single period (100 ns resolution)
- 10^1 periods averaged (10 ns resolution)
- 10^2 periods averaged (1 ns resolution)
- 10^3 periods averaged (100 ps resolution)

Autorange position will automatically seek to fill all 6 digits. Autoranging will not select a period average of greater than 10^2 averages.

Totalizing:
Accumulates up to 999999 counts, then activates overflow indicator

TIME BASE CHARACTERISTICS

Frequency: 10 MHz

Stability:

- Aging Rate: $< \pm 5 \times 10^{-7}$ month
- Short Term: $< \pm 5 \times 10^{-8}$ over 1 second
- Temperature: $< \pm 5 \times 10^{-6}$ 0°C to 50°C
  $< \pm 2 \times 10^{-6}$ (typical) 20°C to 30°C

Line Variation:
$< \pm 1 \times 10^{-7}$ for $\pm 10\%$ variation in line voltage

GENERAL

Display:
6 digit LED, leading zero suppression
Time between successive measurements is 200 ms plus measurement time

Annunciation:
MHz, kHz, msec, µs overflow

Automatic Features:

AUTORANGE:
In both frequency and period modes, autoranging includes a unique 20% hysteresis in its switching thresholds, to eliminate redundant up range/down range commands. This allows measurements to be made on signals containing large amounts of FM and PM.
Hysteresis memory can be reset by depressing the reset button.

AUTORESET:
A new measurement sequence is started every time a front panel button is activated.

Operating Temp: 0°C to +50°C (0°C to +40°C for -01 Battery option if operated from line.

Storage Temp: −40°C to +60°C

Power Requirements:
115/230 VAC ±10% - 100 VAC available - 50, 60, 400 Hz - 6.5 watts line model - 8.5 watts battery model

Fuses:
1/4A AC-line version-½ A slo-blo battery version

DIMENSIONS

Width:	8.55 inches	217.2 mm
Height:	2.52 inches	64.0 mm
Depth:	10.65 inches	270.5 mm
Weight:	2.75 lbs	1.2 Kg

DATA OUTPUT OPTION

8-4-2-1 BCD output from each digit, plus encoded decimal point and units annunciation information. All outputs CMOS Low Power TTL compatible, high true. Print command is provided.

BATTERY

NICAD rechargeable — discharge time 5 hours — charge time 14 hours @ ~ 30°C ambient with unit inoperative

A4.5 DIGITAL CASSETTE RECORDER

DATA FORMAT:

Data format complies with ISO-3407, ECMA-34, JIS-C6281 and other similar standards.

Recording Format:	Phase Encoding
Recording Density:	800 bpi (32 bits/mm, nominal)
Number of Tracks:	Single Track

MECHANICAL CONSTRUCTION:

Tape Drive System:	D.C. Motor Direct Reel Drive System
Tape Speed Detection System:	Encoder Detection
Cassette Insertion:	Pocket Holder type
Cassette Eject Mechanism:	Manual Ejection by depressing EJECT Button
BOT/EOT & Clear Leader Detector:	Photoelectric Detector
Magnetic Head:	Single Track, Single Gap Read/Write Head

POWER REQUIREMENTS:

	Average Current Consumption	Maximum Current Consumption	Permanent Ripple Voltage
D.C.+12V±5%	1.0 A	1.8 A*	Less than 100mVp-p
D.C.+ 5V±5%	0.7 A	0.75A*	Less than 100mVp-p

*Except for surge current at power-on.

GROUND ISOLATION:

Insulation resistance between 0V power supply and frame ground — 5 Meg Ohms or more, at 150V D.C.

ENVIRONMENTAL CONDITIONS:

Temperature range operating +5°C - 40° C; storage -15°C to +60° C

Relative Humidity Range (non-condensing): operating 20% to 80%; storage 10% to 90%

Vibration (operating):	Less than 0.5G (less than 120 Hz)
Impact:	Less than 40G(less than 30 msec)
Continuous:	Less than 3G

OPERATIONAL CHARACTERISTICS:

Tape Speed (Slow):	15 isp (38.1 cm/s) ± 3%
(Fast):	45 ips (114.3 cm/s) ± 4%
IBG:	0.97 ± 0.24 inch (24.64 ± 6.10 mm)
Erased Length	2.19 ∓ 0.27 inch (55.63 ∓ 6.86 mm)
Initial Gap:	2.26 ∓ 0.40 inch (57.40 ∓ 10.16 mm)
Readable IBG Length	0.7 inch (17.78 mm) or more
Required tape length for Long IBG detection	15.0 - 22.2 inch (381.0 - 563.9 mm)
Start distance for HIGH SPEED SEARCH:	2.4 inch (60.96 mm) or less
Stop distance for HIGH SPEED SEARCH:	1.9 inch (48.26 mm) or less
Nominal Data Transfer Rate:	12 k bits/sec
Recording Density	800 bpi ± 4
Threshold Level (at reference read level) (LOW):	18 ± 3
(HIGH):	40 ± 5

A4.6 POCKET ASCII TERMINAL

Specification

Memory:	last 30 characters received
Characters simultaneously displayed:	8 (7 at left home and right home positions)
Character set displayable:	64 ASCII characters and symbols
Formation:	16 segment "starburst"
Number of keys:	40
Transmittable codes:	128
Code transmitted:	8-bit ASCII (framed by 1 start bit, 1 or 2 stop bits)
Compatibility:	RS232 standard (20 mA loop to order)
Size:	6 in x 3 in x 1.4 in
Weight:	0.5 lb
Power supply:	5 V single rail at 400 mA typical

POWER

The Terminal requires a regulated power supply at +5V ± 5 percent. The RS232/C version typically requires 450mA, and the 20mA loop version 400mA.

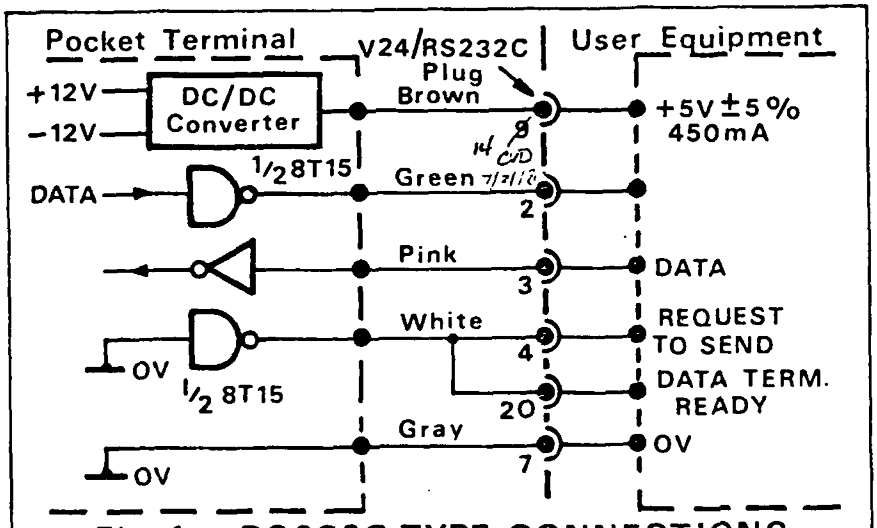
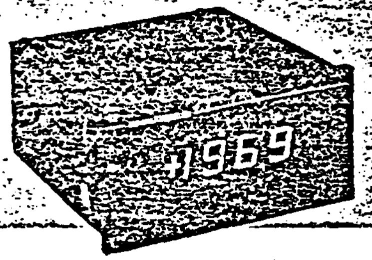


Fig. 1a. RS232C TYPE CONNECTIONS

A4.7 ALTIMETER PANEL METER



AN2570

±1999 count

Full Performance, Low Cost

DIGITAL PANEL INSTRUMENT

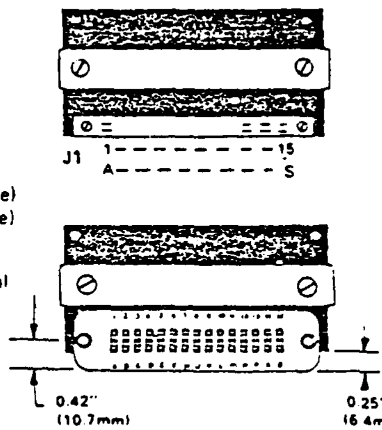
Rear View – Bezel Not Shown for Clarity

A. Standard Card-Edge Connector (Solderable)

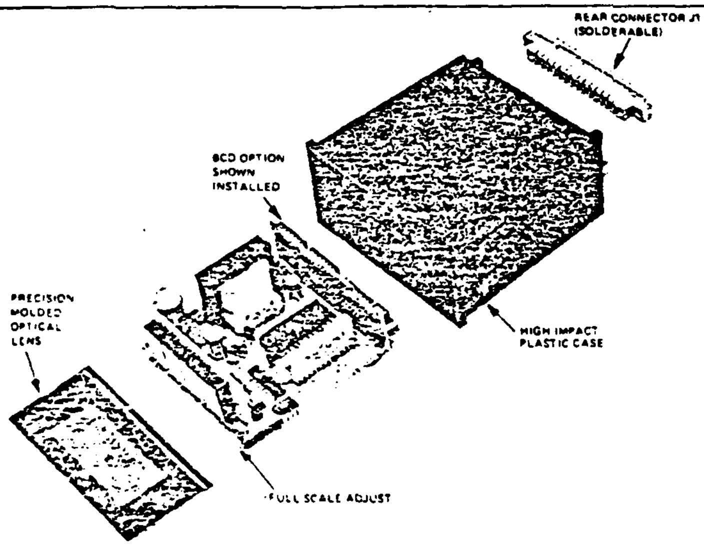
Analogic Part No.s
15-300004P (For plastic case)
15-300004m (For metal case)

B. Optional Screw-Terminal Connector (Solderless)

Analogic Part No.
PL-10-5535



1. Rear Panel Connectors



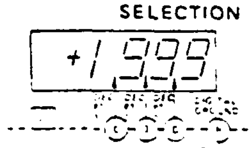
J1 PIN DESIGNATIONS

Ratio Input	A	1	Signal IN (+)*
Analog Ground*	B	2	Signal Return (–)*
Decimal Point 1	C	3	Decimal Point 2
Decimal Point 3	D	4	EOC/HOLD
BCD (2)*	E	5	BCD (1)*
BCD (8)*	F	6	BCD (4)*
BCD (20)*	H	7	BCD (10)*
BCD (80)*	J	8	BCD (40)*
BCD (200)*	K	9	BCD (100)*
BCD (800)*	L	10	BCD (400)*
PRINT*	M	11	DISPLAY TEST
BLANK/OVERRANGE	N	12	BCD (1000)*
–5.1VDC Output	P	13	POLARITY*
Digital Ground†	R	14	+5V†
AC Power IN†	S	15	AC Power or +8 to +28VDC IN†

†POWER CONNECTIONS

+5VDC	Pin 14 for +5VDC, Pin R for Power Return
+8 to +28VDC	Pin 15 for +8 to +28VDC, Pin R for Power Return
110VAC	Pins S and 15
220VAC	Pins S and 15

DECIMAL POINT SELECTION



To display the desired decimal point, simply connect the appropriate pin as shown to Digital Ground (Pin R, J1) using a jumper lead.

A5 RF MODULE

A5.1 MECHANICAL SWITCHES

Microwave Associates - Model 7530 PMD

Frequency (GHz)	Insertion Loss (dBs)	Isolation dBs	VSWR
4.0	0.2	80	1.20
8.0	0.3	70	1.25
12.4	0.4	65	1.4
18.0	0.5	60	1.5

Operating voltage: 20 to 30 VDC; Pull-in = 20 V; Drop-out = 2 V
Coil resistance: 158 to 192 ohms

Hewlett Packard - Model #33311 B

Frequency (GHz)	Insertion Loss (dBs)	Isolation dBs	VSWR
DC-2	0.25	90	1.15
2-18	0.5	90	1.4

Operating voltage: 20 to 30 V
Switching current: 120 mA at 24 V

A5.2 MIXERS

RHG Model DMI-18B; Serial #16-661-1

Frequency (GHz)	Noise Figure (dB)	Lo to Rf Isolation (dB)
1	9	> 20
12	10	> 20
18	10	> 20

WJ Model WJ-M 14

Frequency: 4 to 8 GHz
SSB Conversion Loss: 8.0 dB max
SSB Noise Figure: 8.0 dB max
Isolation: > 20 dB
Insertion Loss: 2 dB

A5.3 CIRCULATORS

Western Microwave	Model 3JC-8019	Model 3JC-4081
Frequency Range (GHz):	8-18	4-8
Insertion Loss (dB):	< .8	< .4
Isolation (dB):	> 15	> 21
VSWR	< 1.6	< 1.2

A5.4 DIRECTIONAL COUPLERS

NARDA	Model 4244	Model 4246
Frequency Range (GHz):	2-8	6.5-18
Coupling:	10	.6
Directivity (dB):	18	17
VSWR:	1.4	1.40
Insertion Loss:	1.00	0.8

A5.5 ISOLATORS

Western Microwave	Model 2JC-401	Model 2JC-818
Insertion Loss (dB):	.4	.8
Isolation (dB):	23	1.3
VSWR:	1.25	1.4

A5.6 RF OSCILLATORS: OPERATING INSTRUCTIONS AND SPECIFICATIONS

Installation

Bias voltage should be within ± 0.2 volts of the correct value to obtain specified operation. At 2 or 3 volts above the correct value the Zener diode, placed in the bias circuit to provide protection, will begin to draw excess current.

CAUTION: If the bias current exceeds the maximum bias current shown on the data sheet by as much as 50 milliamperes, the protective Zener will be endangered. For GaAs oscillators, a current peak up to 200 mA higher than the value recorded on the data sheet may be observed at low (-2 to -4V dc) negative bias levels, however.

If excess current is drawn, check for high bias voltage or reversed bias polarity.

Heaters

Heaters are often included in the oscillator to minimize such temperature effects as frequency drift and power output variation. These heaters are self-regulating and may be operated from an unregulated voltage within the range of 22 to 30 volts. Transients of up to 80 volts in accordance with Figure 6 of MIL-STD-704-A will not normally damage the heater.

Mounting

The oscillator may be mounted in any orientation. The unit (particularly units that tune above 4 GHz) should be mounted to a smooth heat sink capable of dissipating up to 10 watts without raising the temperature at the base of the unit adjacent to the heat sink above the specified operating temperature range. (Use of heat sink compound (e.g., Dow Corning 340) is recommended on mounting surface).

YIG-TUNED GaAs OSCILLATOR

Type No.: 5157-300D Serial No.: 1027 (ER)

Operating Conditions:

Heater Voltage: +28.0 Vdc Current: 180 mA at -54° C
Bias Voltage: ±18.00 Vdc Current: 1050/500 mA

Test Data:

Tuning Vdc	Calculated Frequency (GHz)	Δ Frequency (MHz) +25° C	Power Output (mw) +25° C
0	8.00	0	30
1	9.00	-10	58
2	10.00	-13	62
3	11.00	-10	68
4	12.00	- 6	64
5	13.00	- 3	46
6	14.00	- 2	49
7	15.00	+ 1	41
8	16.00	+ 2	29
9	17.00	+ 1	21
10	18.00	-3	19

Hysteresis: 11 MHz

YIG-TUNED GaAs OSCILLATOR

Type No: 5157-300 DF Serial No: 1092

Operating Conditions:

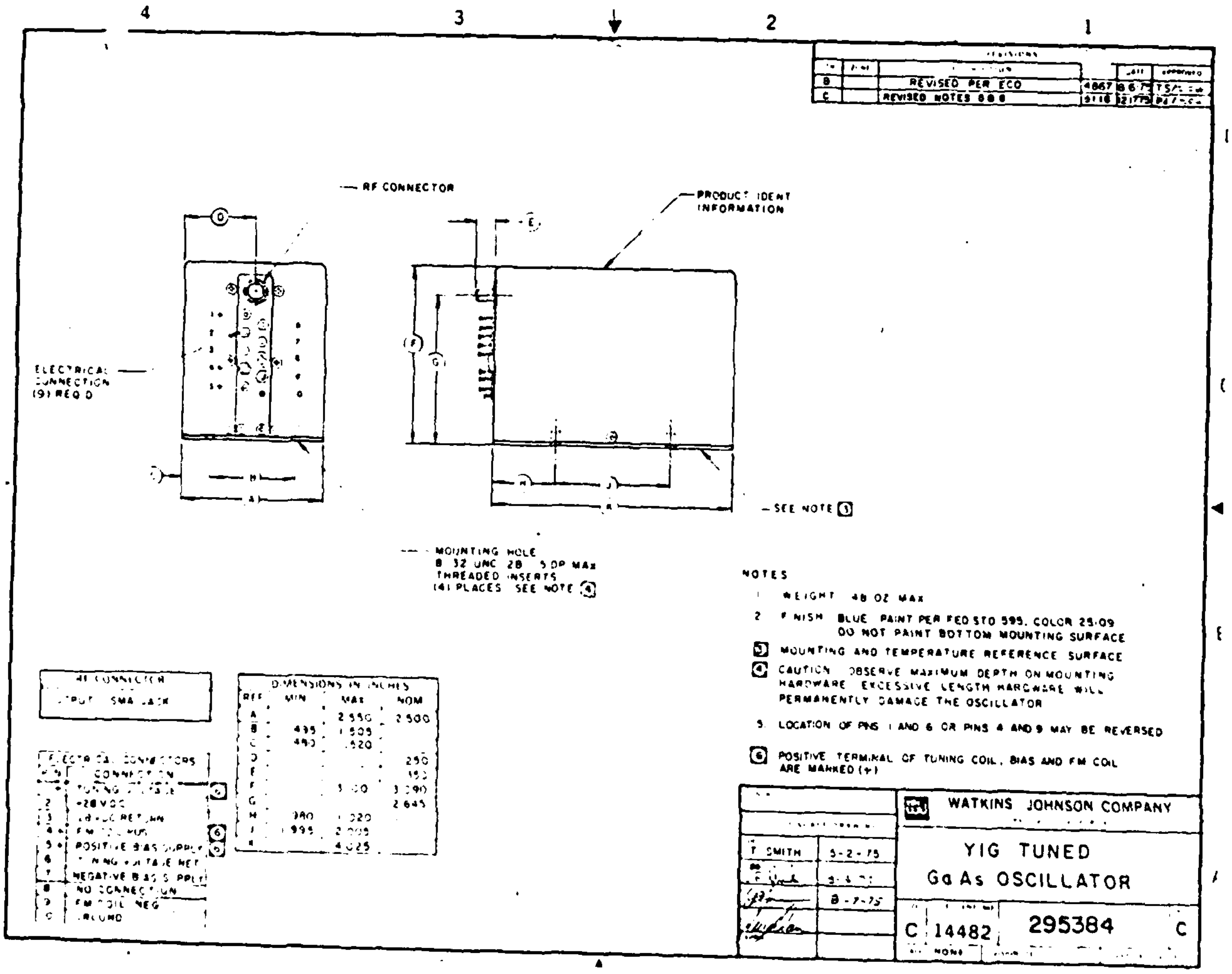
Heater Voltage: +28.0 Vdc Current: 170 mA

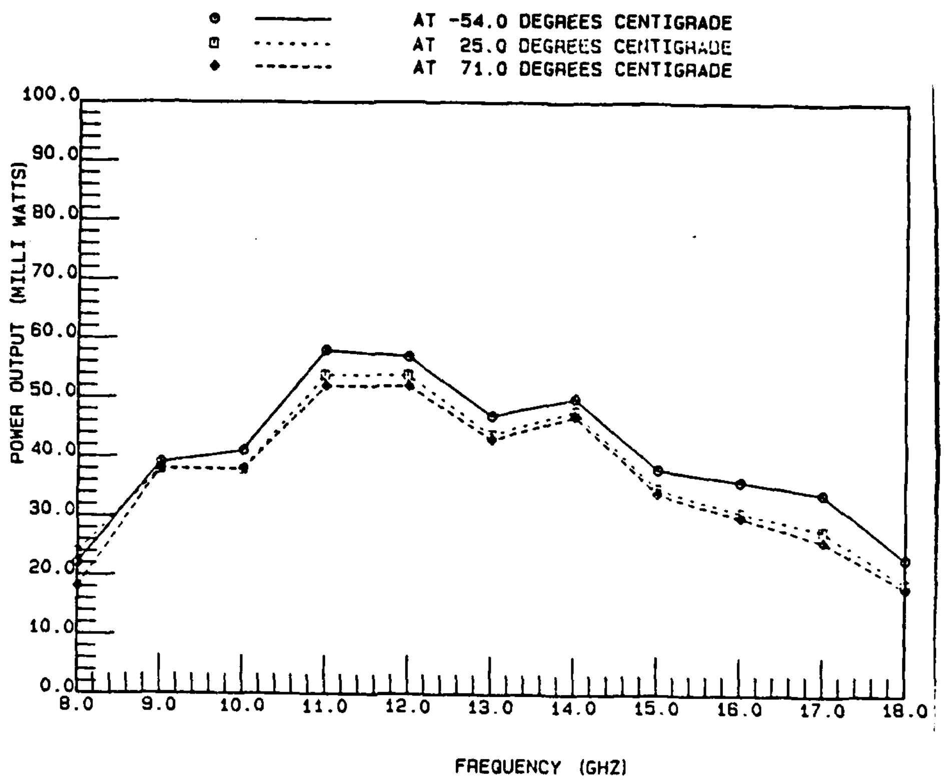
Bias Voltage: +18.00 Vdc Current: 500 mA

Test Data:

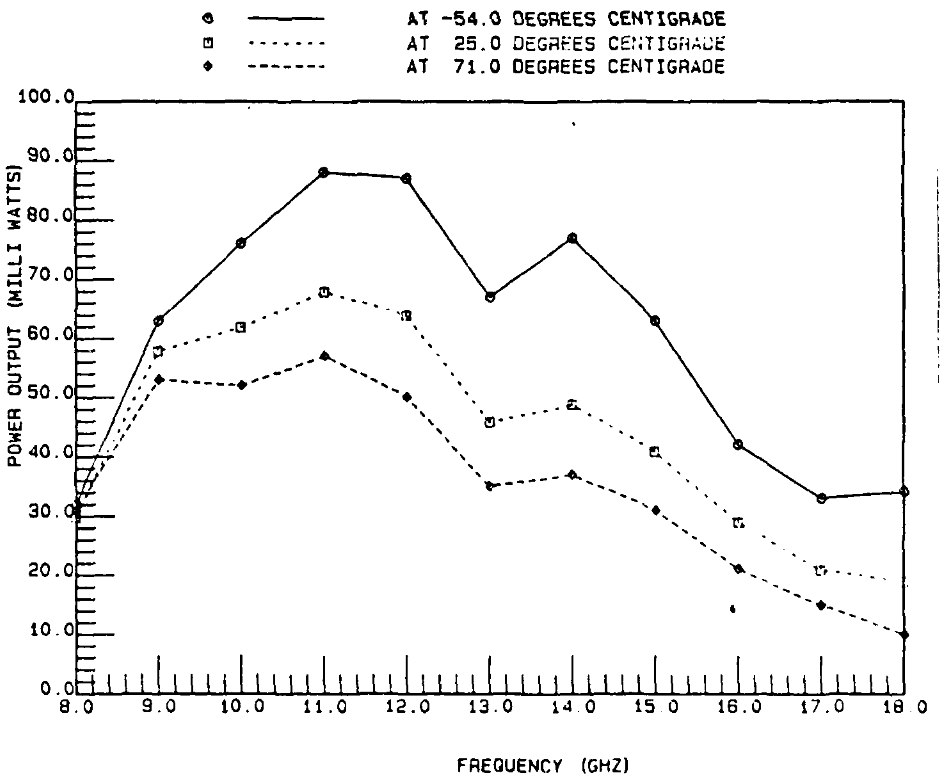
Tuning Vdc	Calculated Frequency (GHz)	Δ Frequency (MHz) +25° C	Power Output (mw) +25° C
0	8.00	0	24.0
1	9.00	+ 1	38.0
2	10.00	+ 9	38.0
3	11.00	+ 7	54.0
4	12.00	+ 9	54.0
5	13.00	+13	44.0
6	14.00	+ 9	48.0
7	15.00	+16	35.0
8	16.00	+10	31.0
9	17.00	+ 5	28.0
10	18.00	0	19.0

Hysteresis: 8.0 MHz





POWER OUTPUT, YIG-OSCILLATOR MODEL# 5157-300DF



POWER OUTPUT, YIG-OSCILLATOR MODEL# 5157-300D

YIG-TUNED TRANSISTOR OSCILLATOR

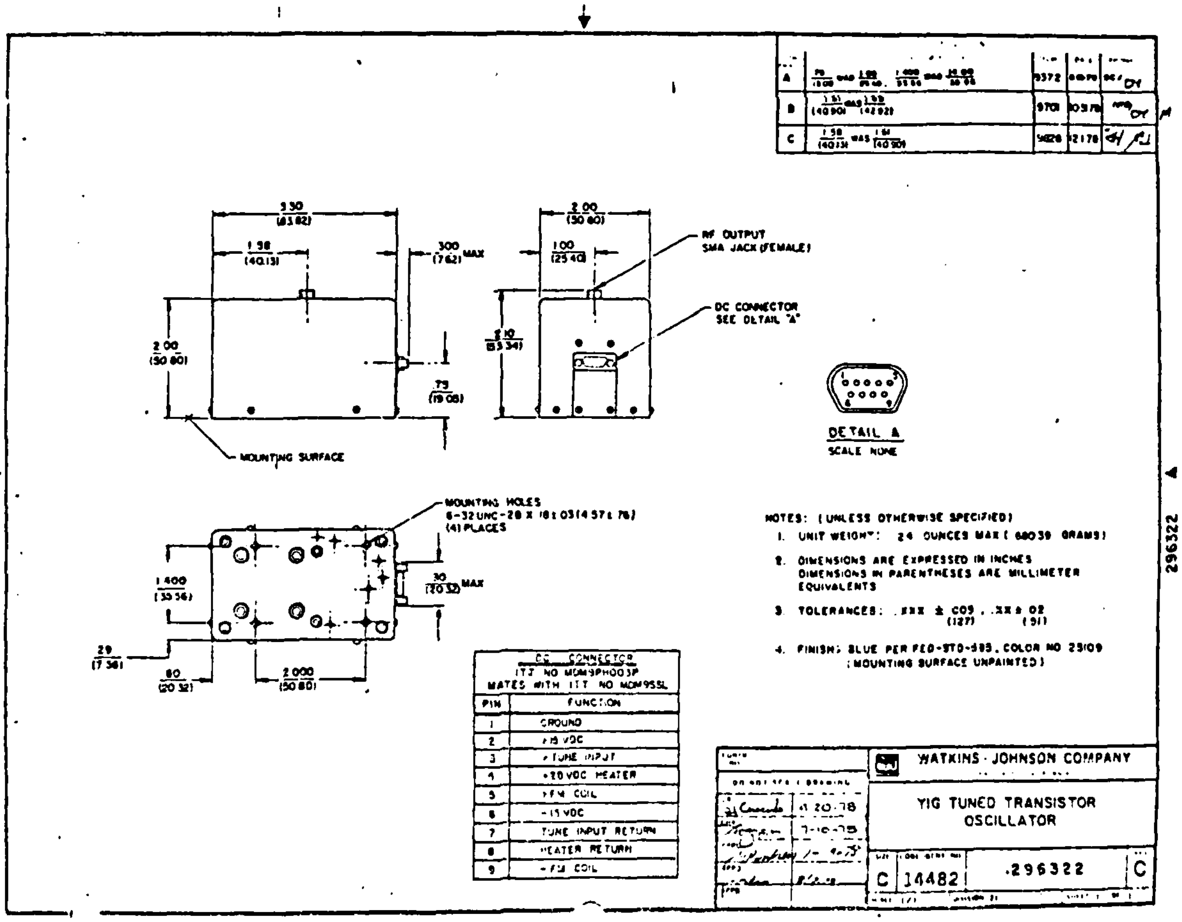
Type No.: 6708-304F   Serial No.: 1094 (Catalog Item)

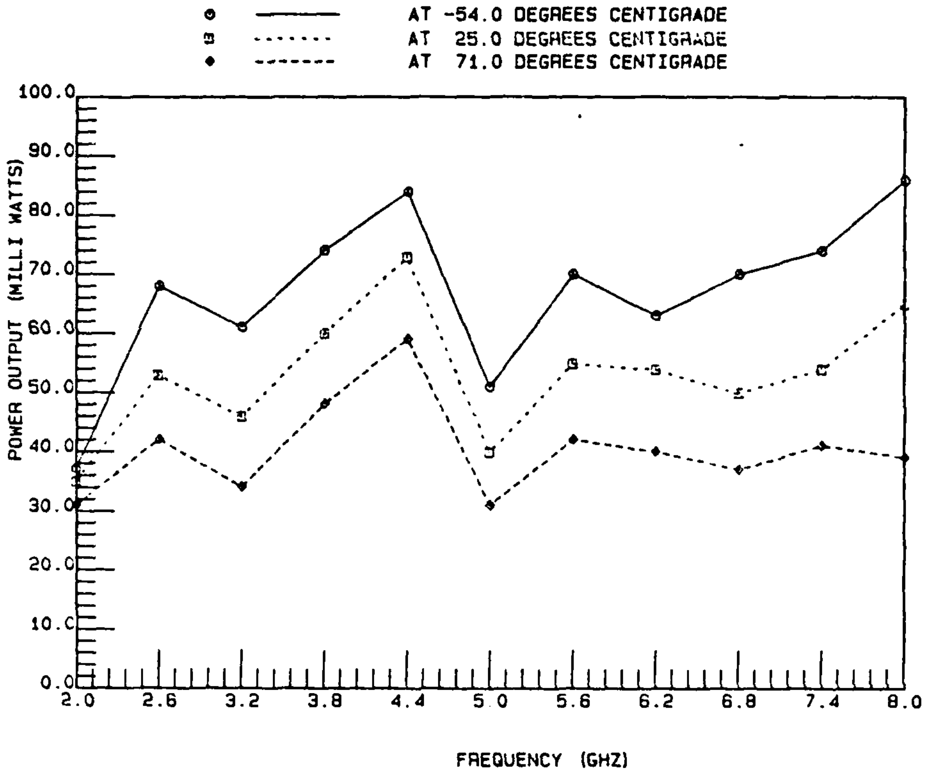
Operating Conditions:

Heater Voltage:	28 Vdc	Current:	26 mA
Transistor Voltage:	+15 Vdc; -15 Vdc	Current:	643 mA; 44 mA

Tuning Voltage (V)	Calculated Frequency (GHz)	Frequency Deviation (MHz) 25° C	Power Output (mW) 25° C
0	2.0	0	35
1	2.6	- .8	53
2	3.2	- .3	46
3	3.8	+1.4	60
4	4.4	+2.1	73
5	5.0	+4.8	40
6	5.6	+7.2	55
7	6.2	+7.1	54
8	6.8	+9.0	50
9	7.4	+9.5	54
10	8.0	- .2	65

Drift: 7.7 MHz (max)   Hysteresis: 8 MHz





POWER OUTPUT AT DIFFERENT TEMP

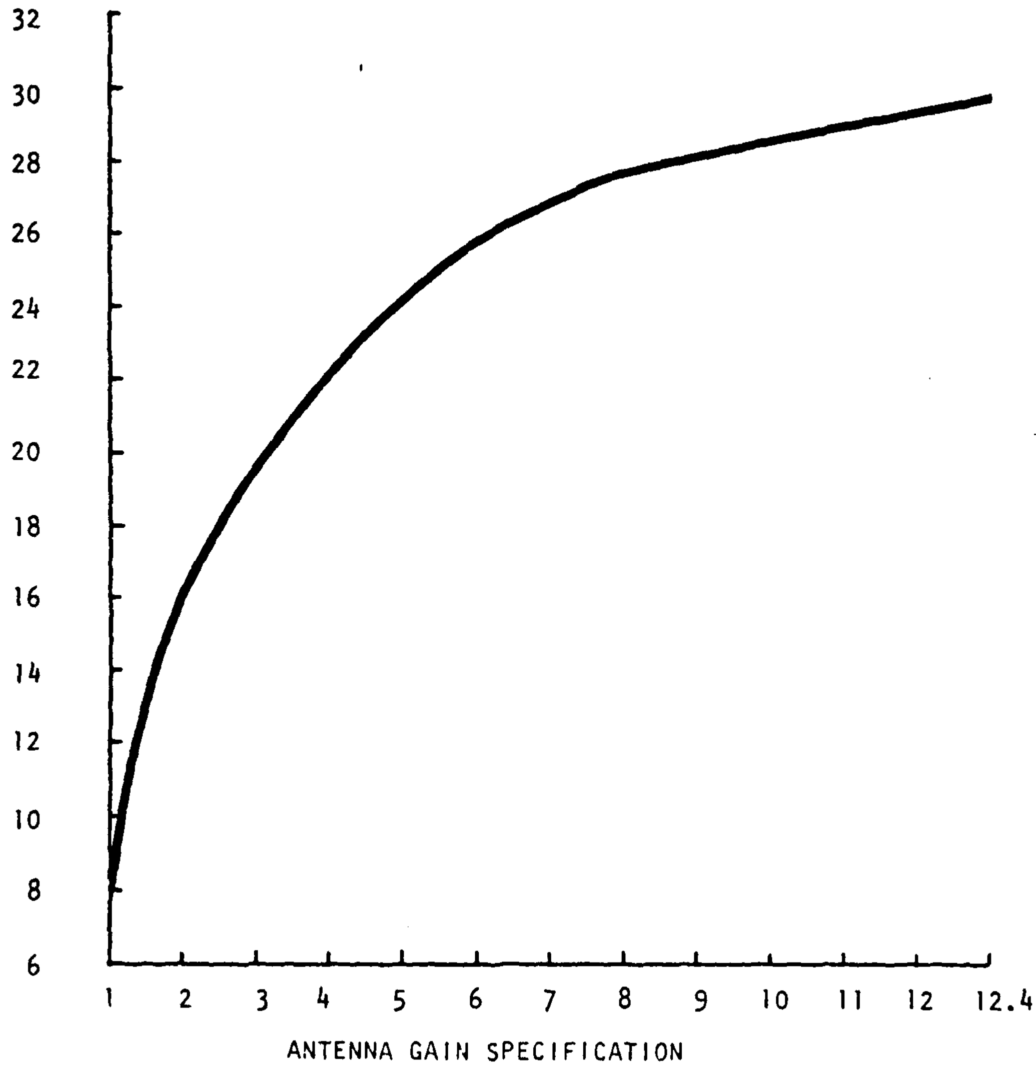
A6 ANTENNAE

PERFORMANCE SPECIFICATIONS

ANTENNA MODEL NUMBER	FREQ RANGE (GHz)	EFFECTIVE DIAMETER in.	EFFECTIVE DIAMETER cm	VSWR (MAX)	GAIN dBi	HOW POLAR-IZED	FRONT TO BACK RATIO MIN dB ON	SQUINT (MAX)	SIDE LOBES MIN. dB ON	3 dB BEAMWIDTH
AR168-AS	1.0 TO 12.4	18	46	3.1**	18 (2 GHz)** 29 (12.4 GHz)	LINEAR	14 dB	1°*	10 dB*	30° (1 GHz) 3° (12.4 GHz)

PHYSICAL SPECIFICATIONS

MODEL NUMBER	"A" in.	"B" in.	WEIGHT lb.	"A" cm	"B" cm	WEIGHT kg	CONNECTORS
AR168-AS	20	18	4	51	46	1.81	N FEMALE



Parabolic Dish Center Feed 18"

Manufacturer	Cost	Model	CRINC Number
Watkins-Johnson	$2,675.00	WJ8572-11	1122

This is a dual-ridge linear-polarized-feed antenna.

Frequency (GHz):	8-18.00
Polarization:	linear
Beamwidth*	suitable for reflector feed
Type:	dual-ridge horn
Output flange:	WRD 750; radome cover included

*Antenna patterns and other miscellaneous details are included in the Appendix.

Parabolic Dish Center Feed 12" Antenna

Manufacturer	Cost	Model	CRINC Number
Watkins-Johnson	$2675.00	WJ8572-12	1123

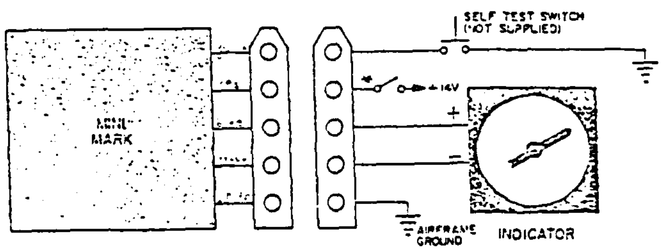
The feed for this antenna is the same as the 18" dish. The only difference is that the diameter of the reflector is 12.0".

A7 RADAR ALTIMETER

Manufacturer	Model	Serial Number
Bonzer	Mini-Mark	M0837

Altitude range:	80 to 1000 (ft)
Output voltage:	80 mV to 1 (V)
Power requirement:	+ 14 V DC

WIRING DIAGRAM



*In order to comply with FCC transmitter rules, paragraph 87.75 (c) (2), a MINI-MARK "ON-OFF" switch available to the aircraft operator must be provided.

Wiring diagram for radar altimeter.

APPENDIX B

WIRING DIAGRAMS

B1: INVERTER/ACTUATOR MODULE

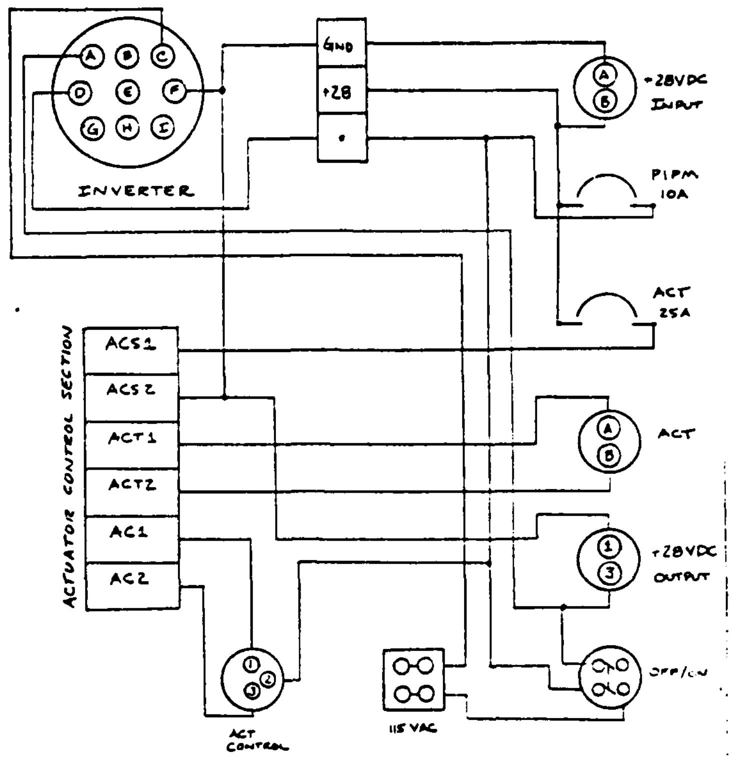


Figure B1.1: Inverter Module

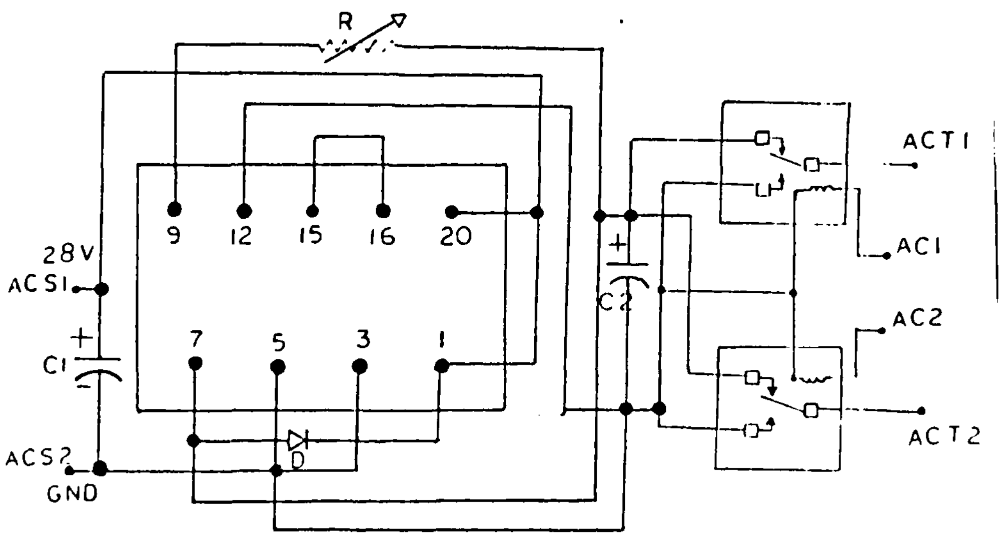


Figure B1.2: Actuator Control Section

B2: DC POWER MODULE

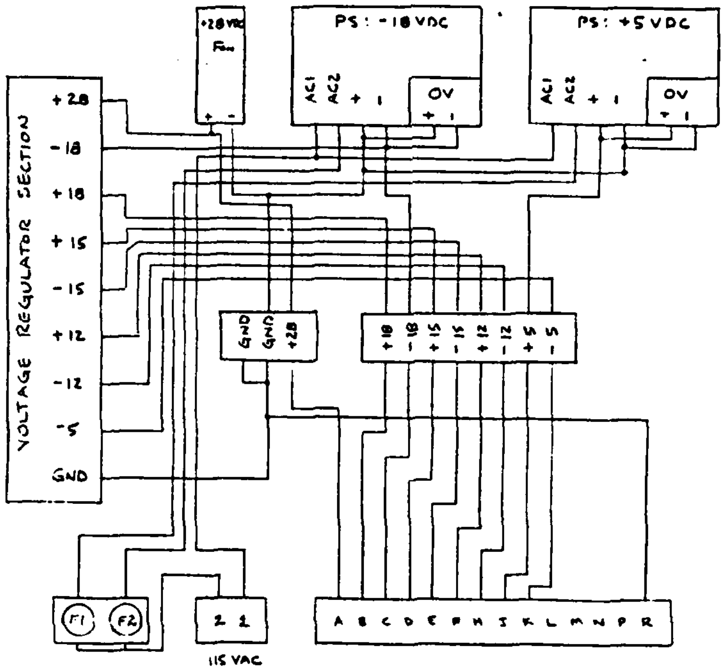


Figure B2.1: Power Supply Module

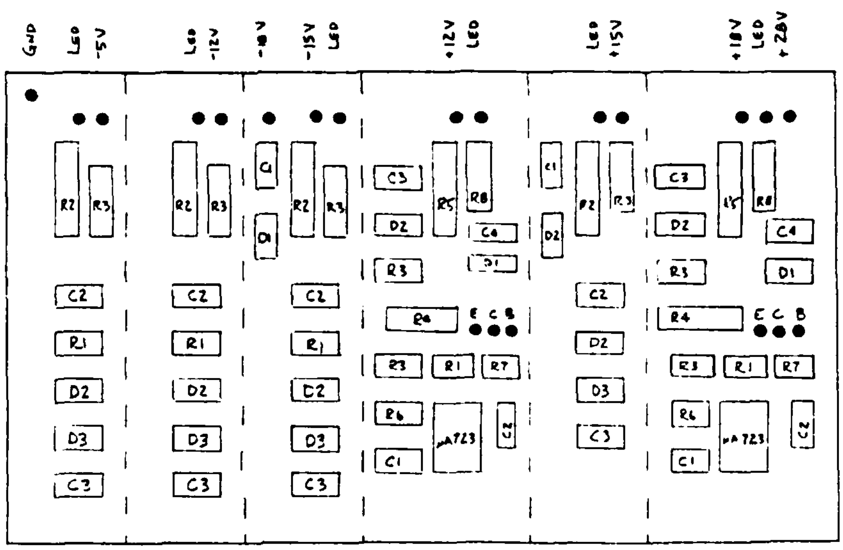
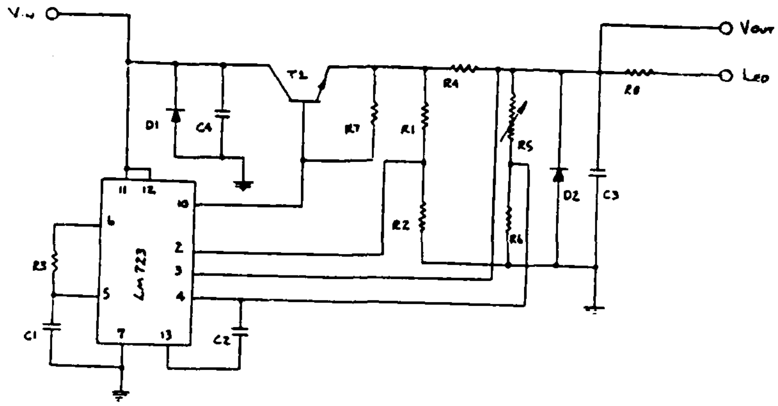


Figure B2.2: Voltage Regulator Board



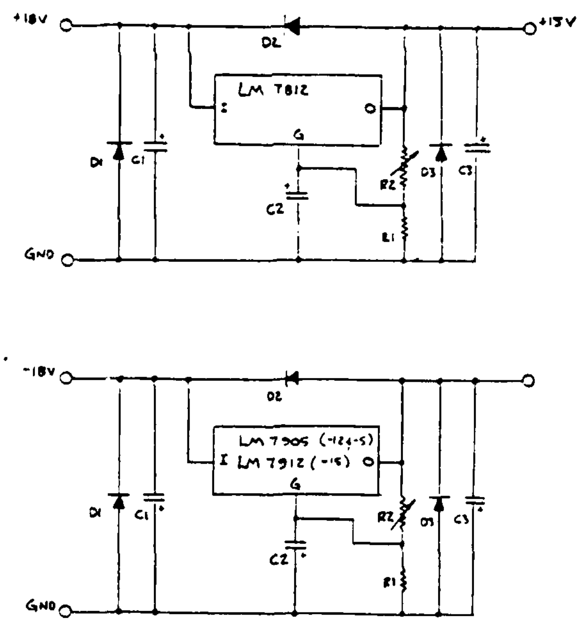
R1 = 27Ω
R2 = 1kΩ
R3 = 33kΩ
R4 = .5Ω, 10W
R5 = 10kΩ
R6 = 6.8kΩ
R7 = 1kΩ
R8(+18) = 820Ω
R8(+12) = 470Ω

C1, C2 = 100pF
C3, C4 = 47µF, 35V
D1, D2 = 1N4002

T1 = 2N6383

V_{IN} = +28V : V_{OUT} = +18V
V_{IN} = +18V : V_{OUT} = +12V

Figure B2.3: +18 V, +12 V Regulators



C1, C2, C3 = 47µF, 35V
D1, D2, D3 = 1N4002
R1 = 750Ω
R2 = 10kΩ
R3(+18) = 500Ω
R3(-15) = 560Ω
R3(-12) = 470Ω
R3(-5) = 150Ω

Figure B2.4: +15 V, -15, -12, -5 V Regulators

B3: FM/IF MODULE

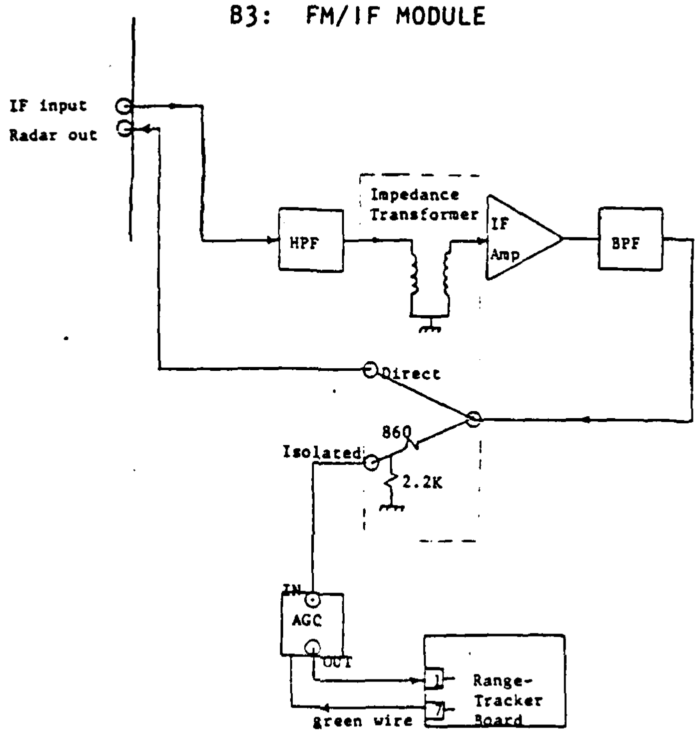


Figure B3.1: FM/IF Module Signal Path

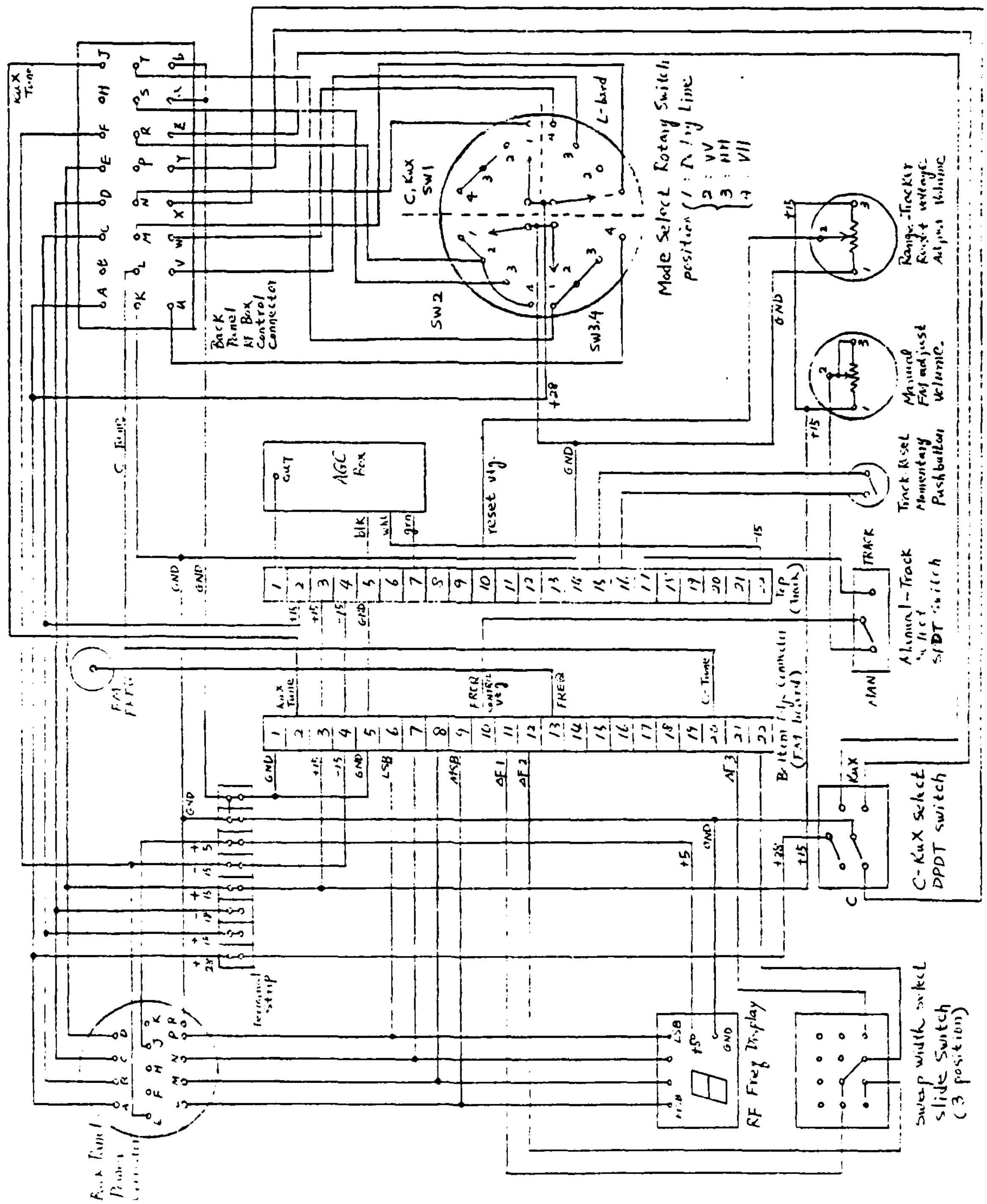


Figure B3.2: FM/IF Module Wiring

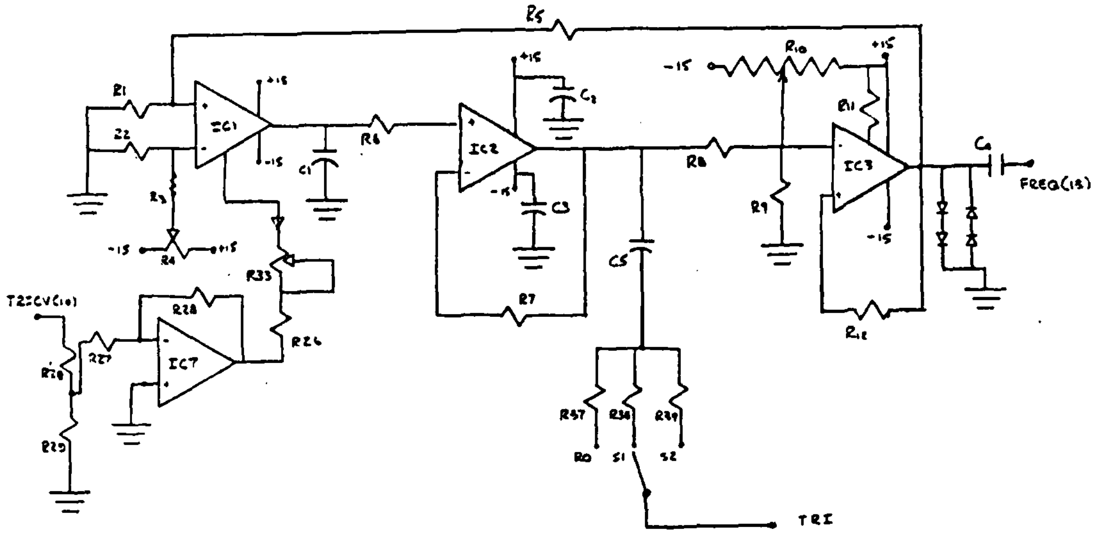


Figure B3.3a: Ku-X-C-Band FM Board, VCO Section
(See component identification on Fig. B3.3c)

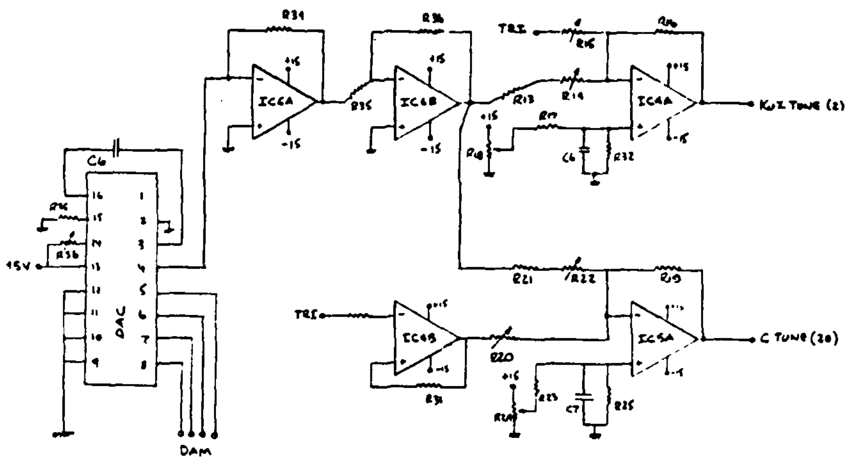


Figure 3.3b: KU-X-C-Band FM Board, Tuning Signal Generator Section
(See component identification on Fig. B3.3c)

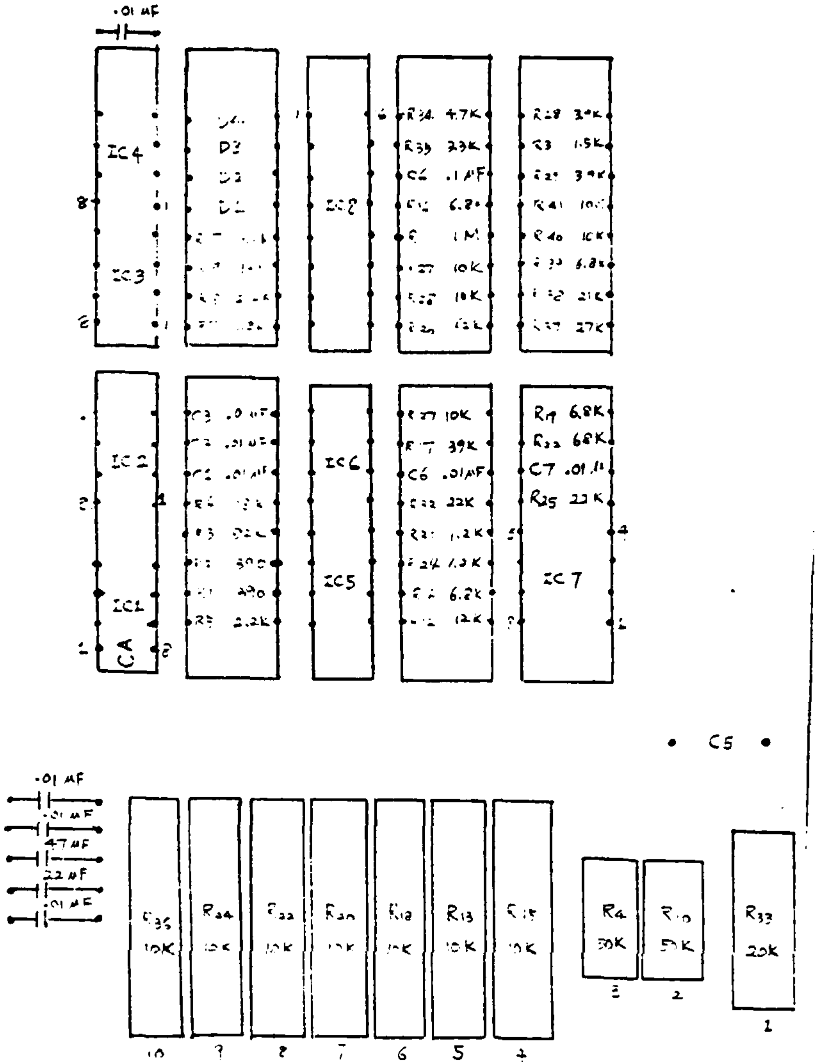


Figure 3.3c: Ku-X-C-Band FM Board, Layout

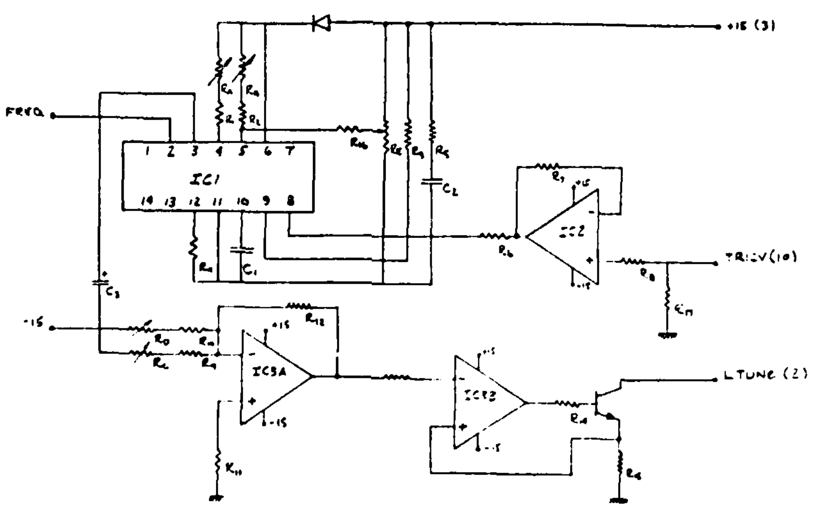


Figure 3.4a: L-Band FM Board, Circuit (See component identification on Fig. B3.4b)

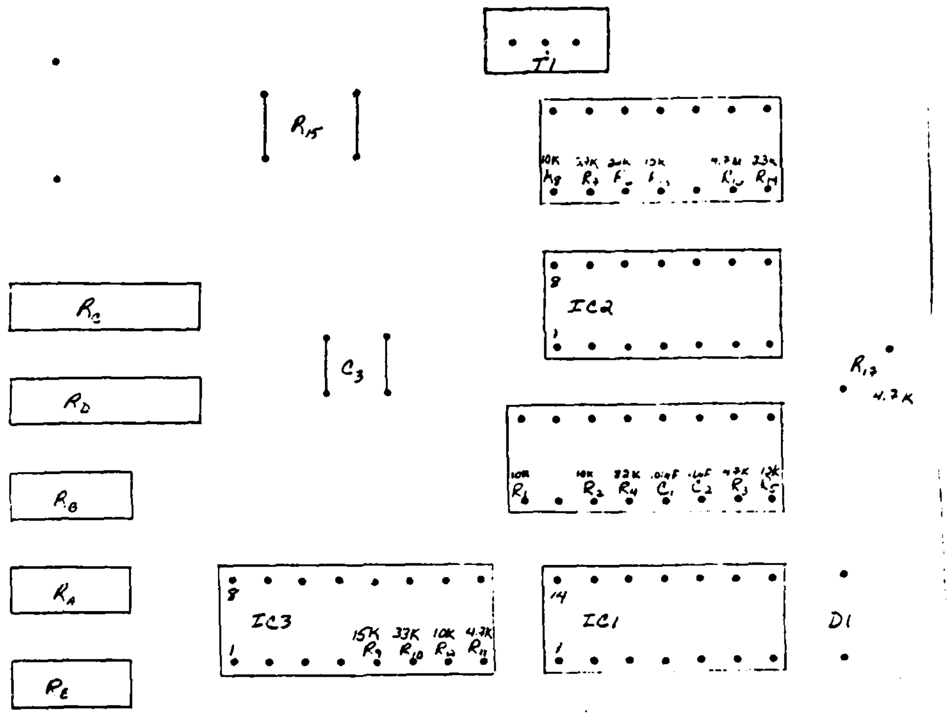


Figure B3.4b: L-Band FM Board, Layout

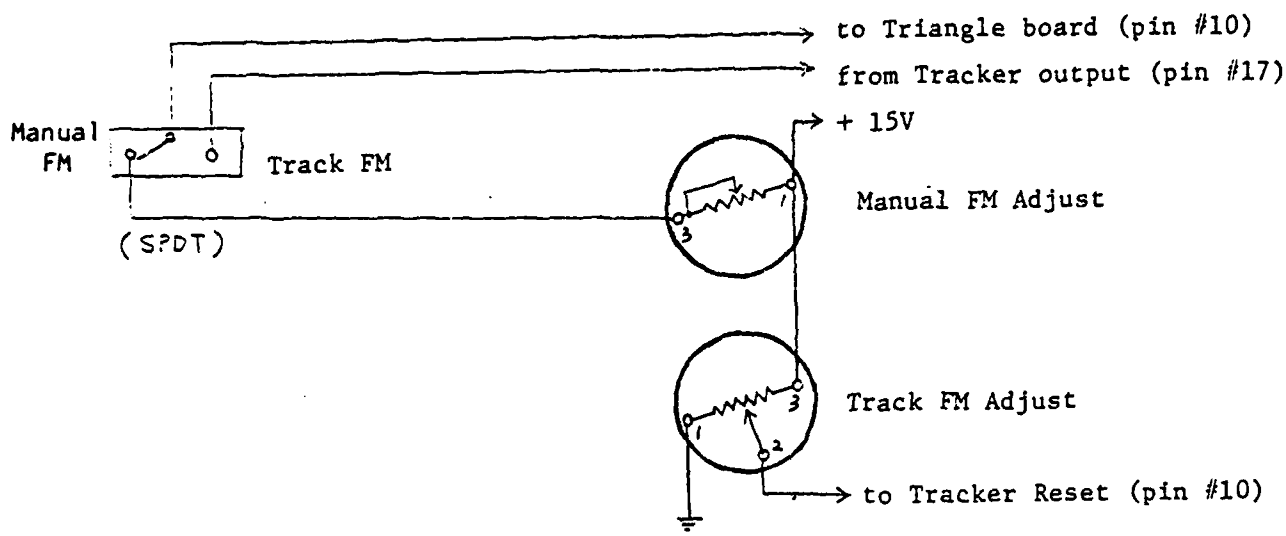


Figure B3.5: Manual-Track FM Control. Controls on front panel of FM/IF module.

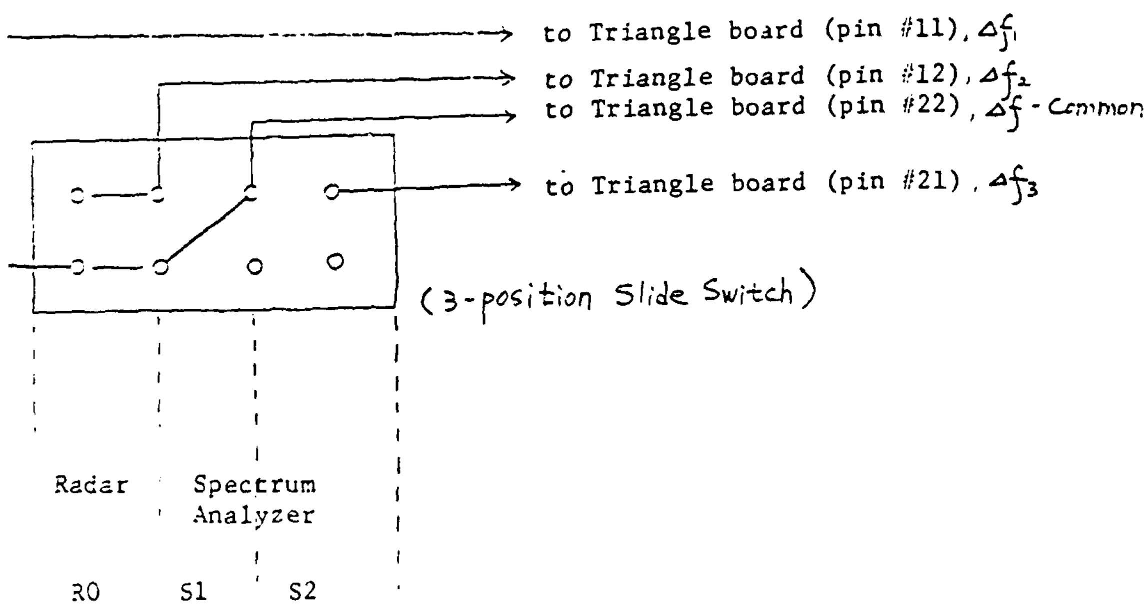
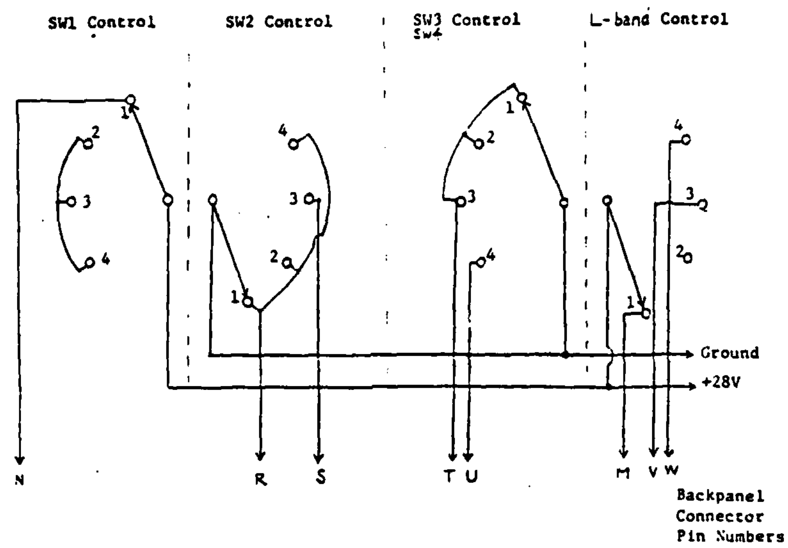


Figure B3.6: RF Sweep Width Control. (Same as above).



Position 1; Delay Line
2; VV
3; HH
4; VH

Figure B3.7: Radar Mode Select Rotary Switch

Pin #	
1	Ground
2	Ku-X-Band, Output
3	15 V
4	-15 V
5	Ground
6	LSB
7	LSB + 1
8	MSB - 1
9	MSB
10	Control voltage
11	To switch
12	To switch
13	To frequency counter
14	NC
15	NC
16	NC
17	NC
18	NC
19	NC
20	C triangle output
21	To switch
22	Input to OP/amp

Figure B3.8a: Edge Connector Wiring, FM Board

1	Signal input from AGC section
2	+18 V
3	+15 V
4	-15 V
5	GND
6	NC
7	Signal feedback to AGC section
8	NC
9	NC
10	Reset voltage from track FM adjust pot.
11	NC
12	NC
13	NC
14	NC
15	Reset push button
16	Reset PUsh button
17	Tracker output voltage, to man-track switch
18	NC
19	Test point, discriminator output
20	NC
21	Test point, input to discriminator section
22	-15 V to AGC section

Figure B3.8b: Edge Connector Wiring Tracker Board

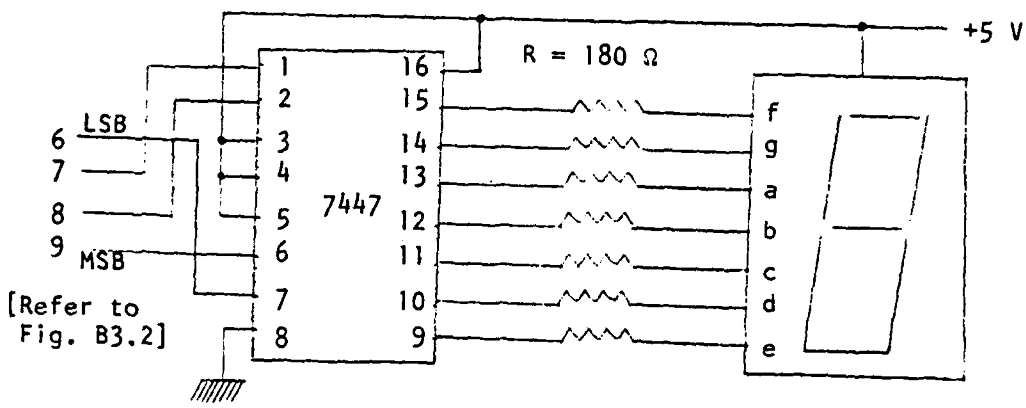


Figure B3.9a: RF Frequency Display Circuit

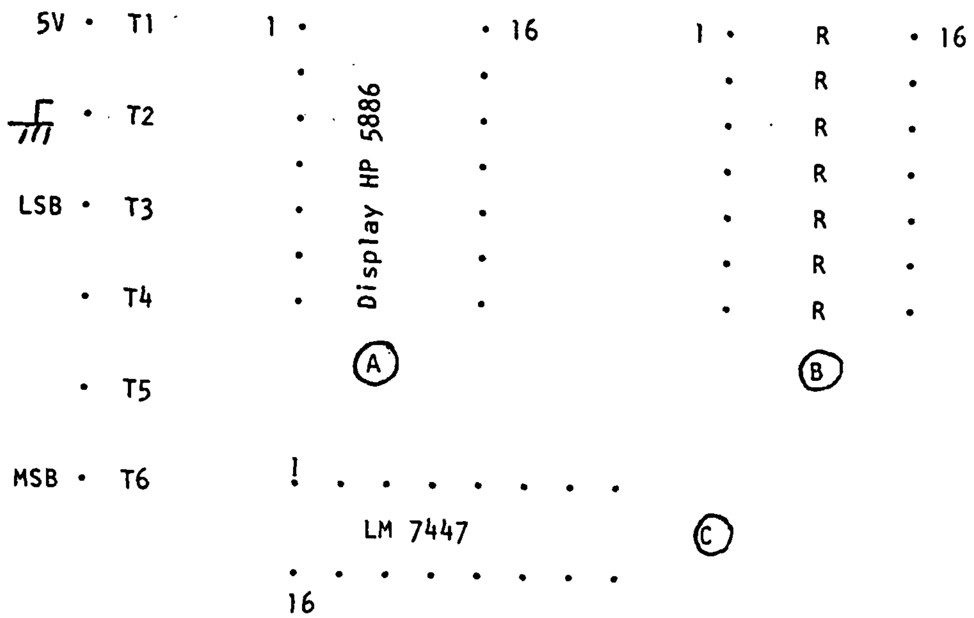


Figure B3.9b: Layout and Display Board

Wiring List:

A1	-	B1	A13	-	B7
A2	-	B2	B16	-	C15
A3,A14	-	T1	B14	-	C9
C3,C4,C5,C16	-	T1	B13	-	C10
A7	-	B3	B12	-	C11
A8	-	B5	B11	-	C14
A11	-	B6	B10	-	C12

B4: DATA ACQUISITION MODULE

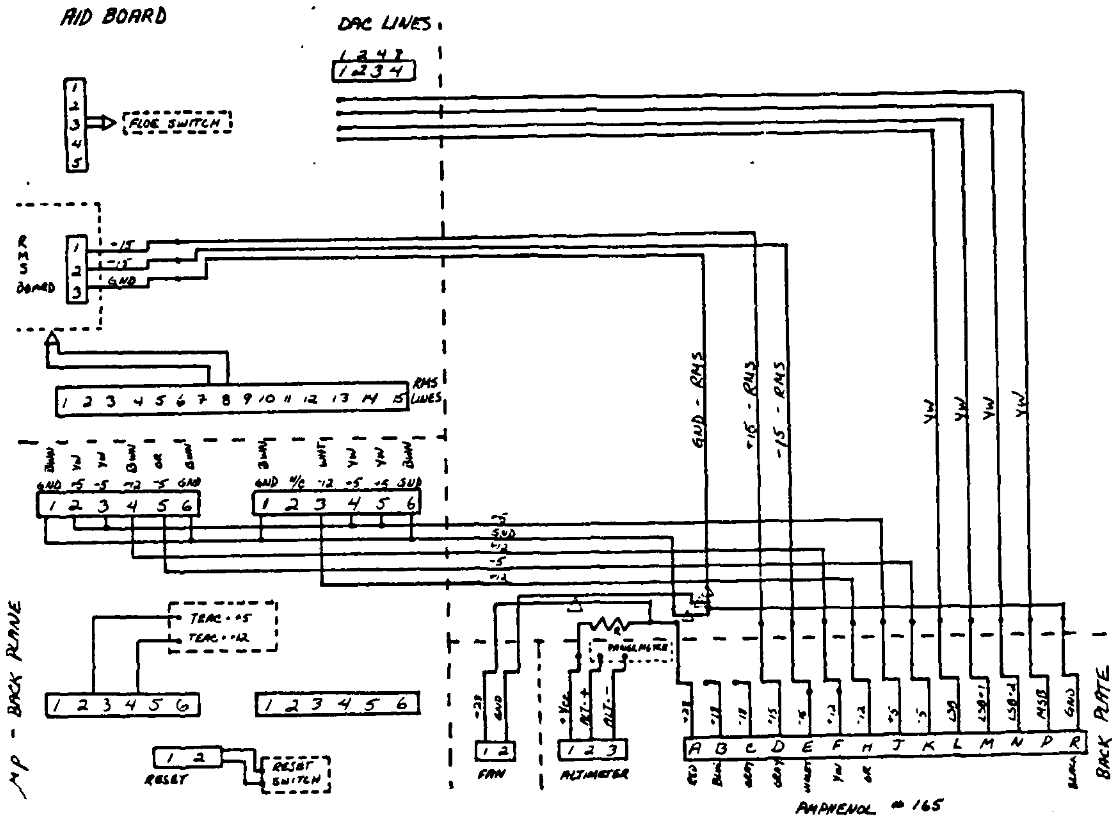


Figure B4.1a: Data Acquisition Module

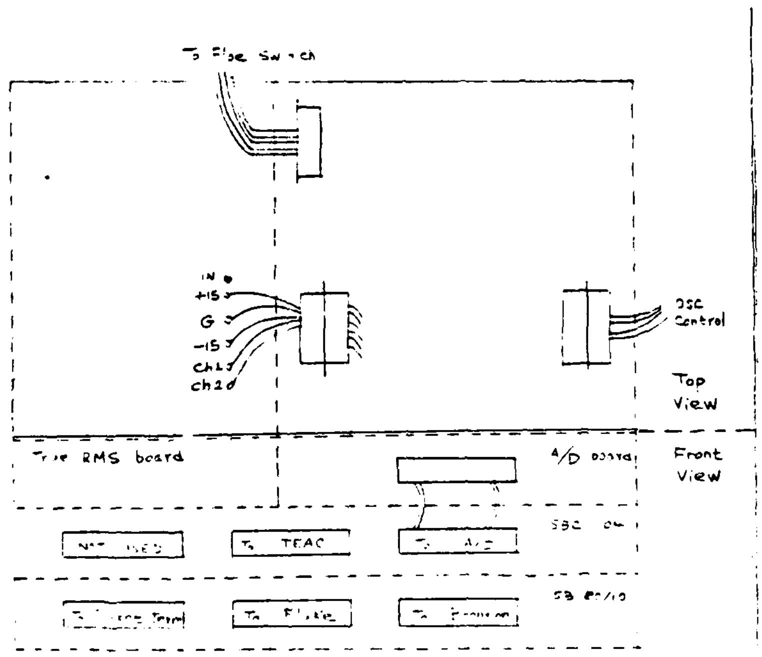


Figure B4.1b: Data Acquisition Module (Layout-Back View)

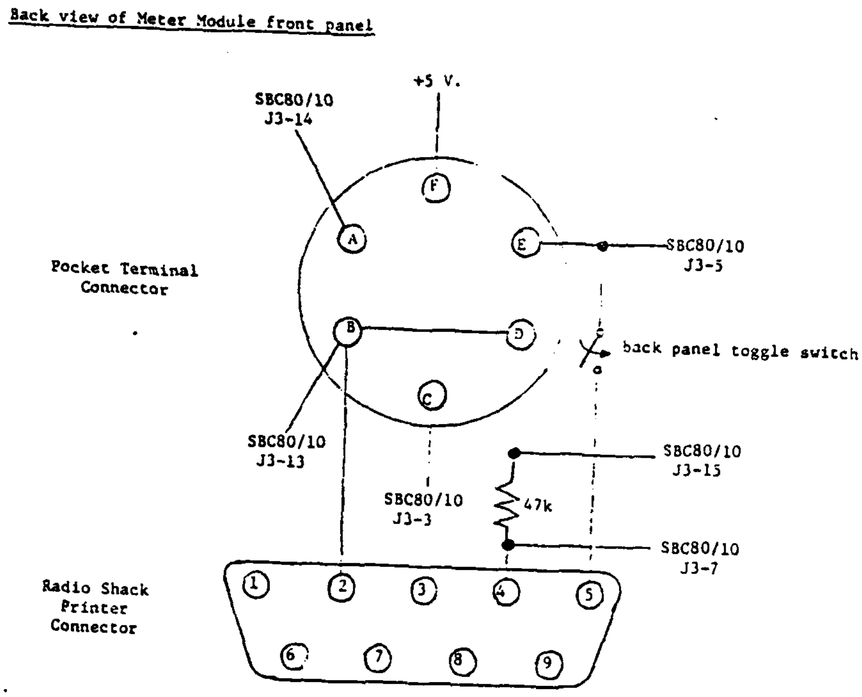


Figure B4.2: Front Panel Connectors

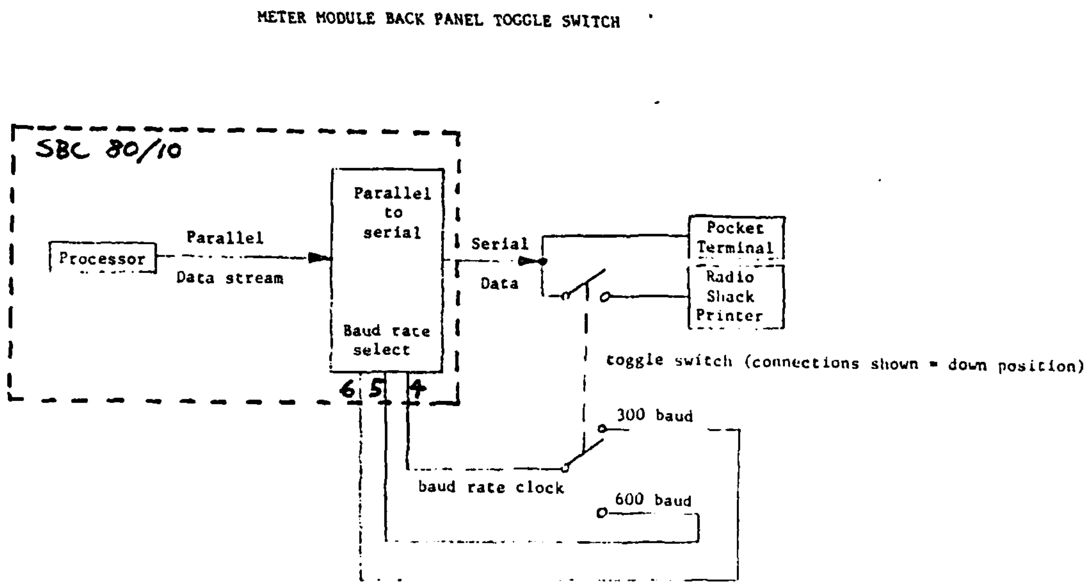


Figure B4.3: Back Panel Toggle Switch

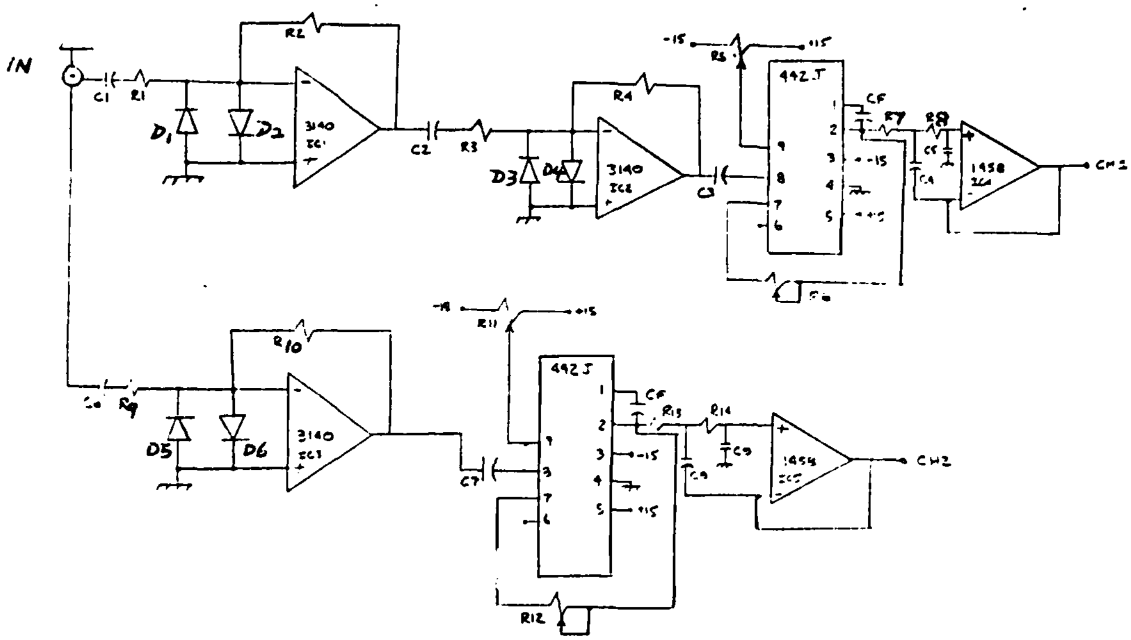


Figure B4.4a: RMS Board, Circuit

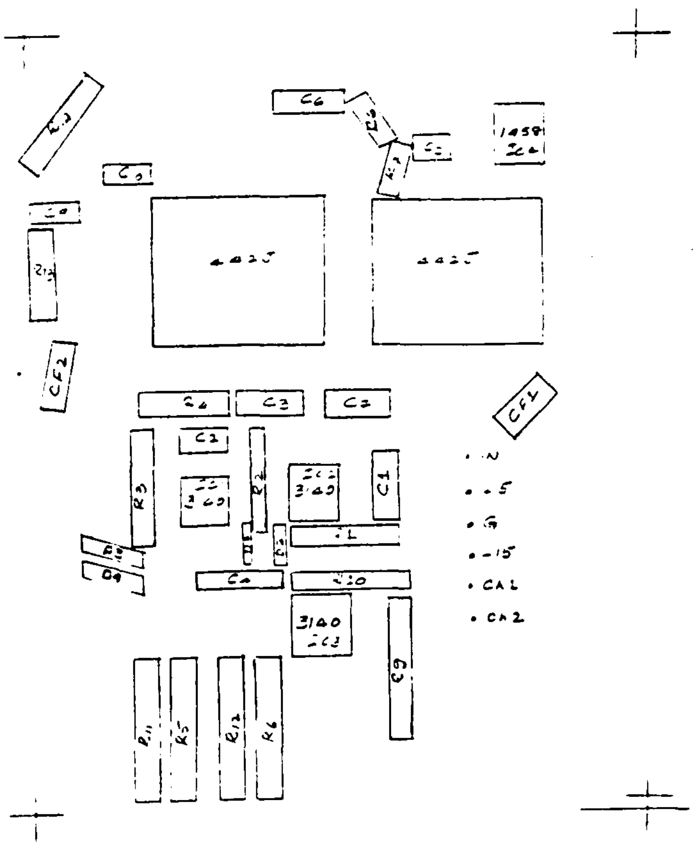


Figure B4.4b: RMS Board, Layout

Parts List:

D1, D2, D3, D4, D5, D6 - IN914
R5, R11, R12, R6 - 20 kΩ
R7, R8, R13, R14 - 47 kΩ
C1, C2, C3, C6, C7 - 10 MF
R9 - 10 kΩ
R10 - 33 kΩ
CF - 1 MF
C4, C8 - 0.47 MF
C5, C9 - 0.2 MF

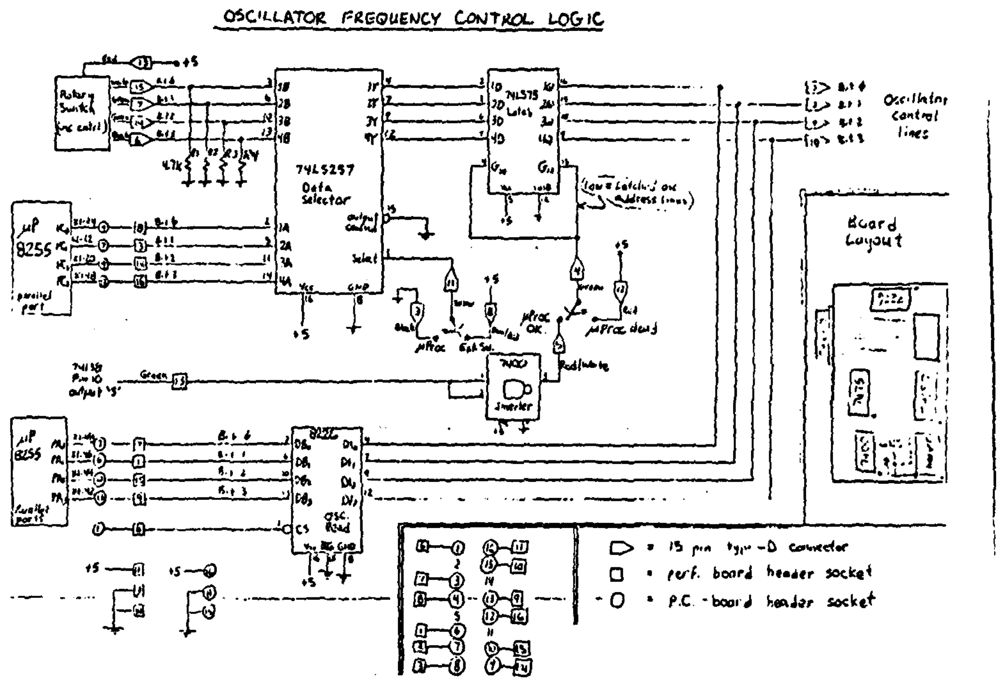


Figure B4.5: Oscillator Frequency Control Circuit

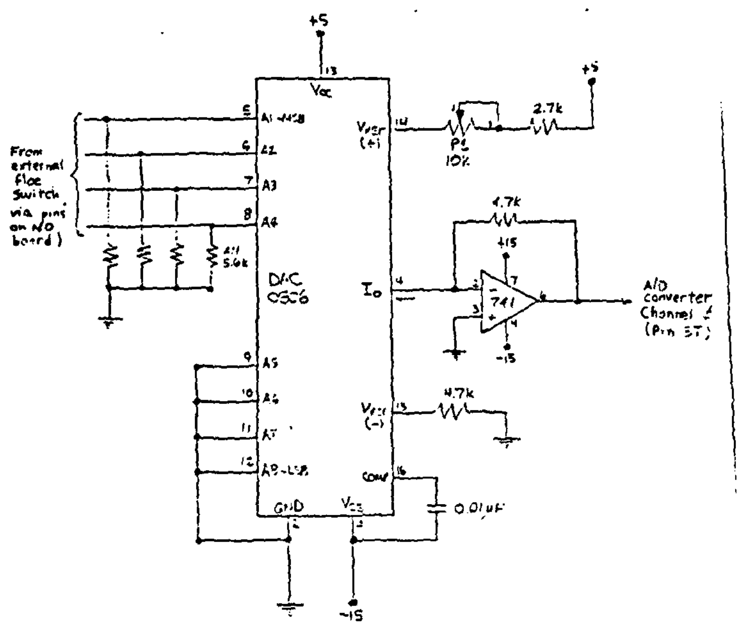
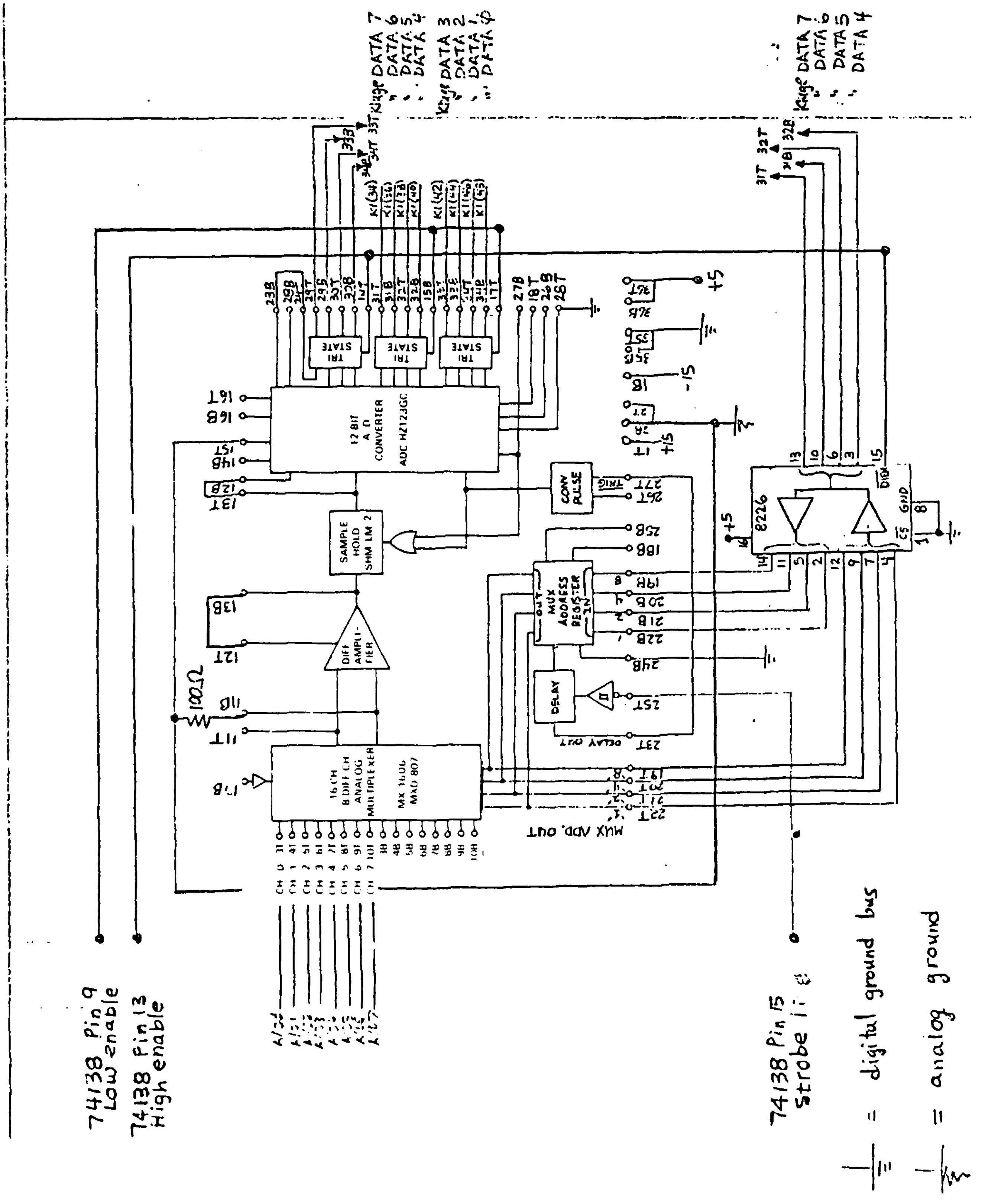


Figure B4.6: Floe Switch D/A Converter

Figure B4.7a: A/D Converter Module



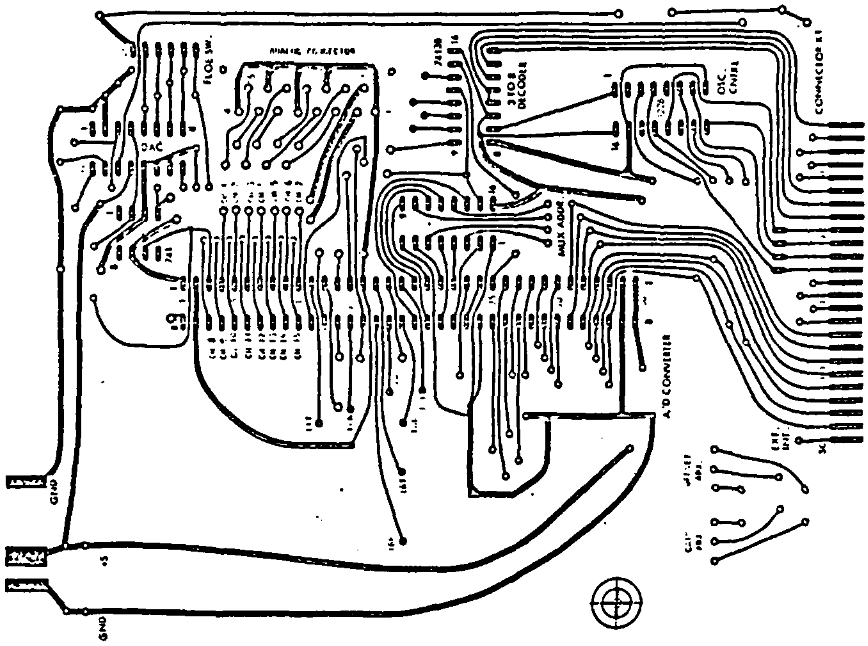


Figure B4.7b: A/D Converter Layout

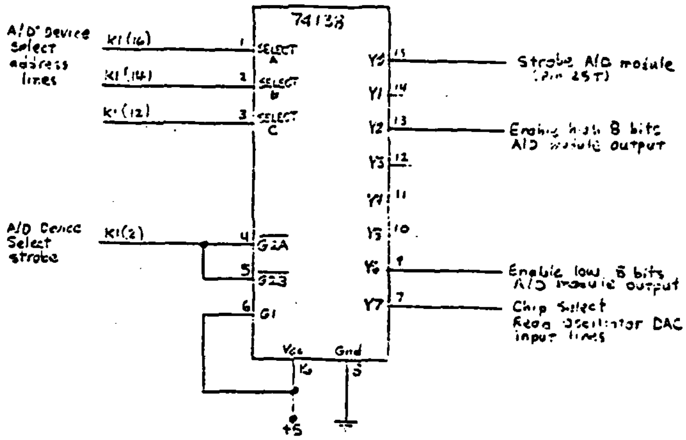


Figure B4.7c: A/D Converter Device Select

Pin #	Signal
2	A/D device select strobe
4	
6	
8	
10	
12	A/D device select address line 'C'
14	" " " " " 'B'
16	" " " " " 'A'
18	Oscillator control bit 3
20	" " " 2
22	" " " 1
24	" " " 0
26	
28	
30	
32	
34	Kluge data bit 7
36	" " " 6
38	" " " 5
40	" " " 4
42	" " " 3
44	" " " 2
46	" " " 1
48	" " " 0
50	

Figure B4.7d: A/D Board Edge Connector 'K1'

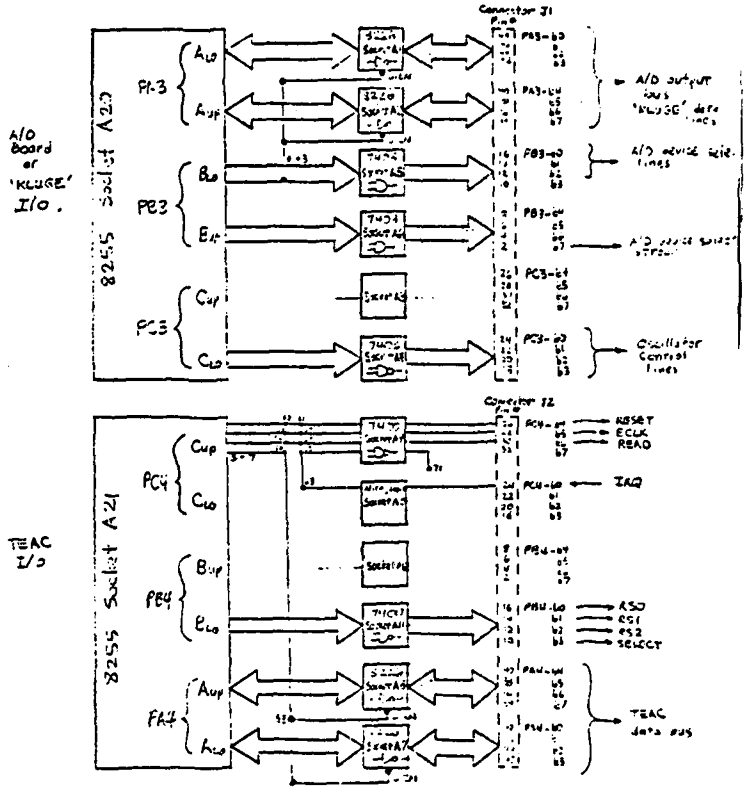
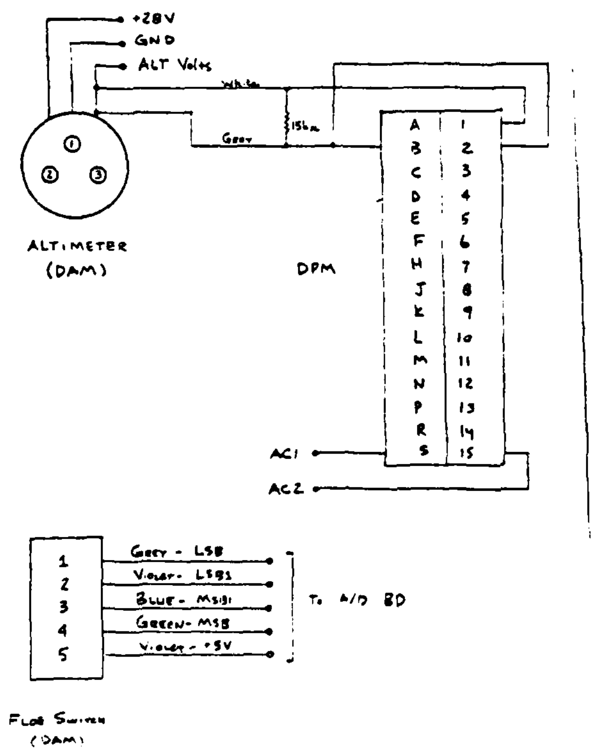


Figure B4.8: SBC104 Parallel Ports



DAM - Data Acquisition Module
DPM - Digital Panel Meter in DAM

Figure B4.9: Panel Meter, Floe Switch Wiring

TEAC end Signal	Connector #		Connector #	Processor end SBC104 J2 #	Signal
N.C.	1				
Frame ground	2				
RESET	3		25	26	PC4 b4
gnd	4		26	25	
ECLK	5		27	28	PC4 b5
gnd	6		28	27	
READ	7		29	30	PC4 b6
gnd	8		32	31	
D7	9		33	34	PA4 b7
gnd	10		34	33	
D6	11		35	36	PA4 b6
gnd	12		36	35	
D5	13		37	38	PA4 b5
gnd	14		38	37	
D4	15		39	40	PA4 b4
gnd	16		40	39	
D3	17		41	42	PA4 b3
gnd	18		42	41	
D2	19		43	44	PA4 b2
gnd	20		44	43	
D1	21		45	46	PA4 b1
gnd	22		46	45	
D0	23		47	48	PA4 b0
gnd	24		48	47	
SELECT	25		9	10	PB4 b3
gnd	26		10	9	
IRQ	27		23	24	
gnd	28		24	23	
N.C. (DRQ)	29	(see p. [illegible] TEAC manual)			
gnd	30				
DACK	31	1K (see p 2421)			
gnd	32				
RS2	33		11	12	PB4 b2
gnd	34		12	11	
RS1	35		13	14	PB4 b1
gnd	36		14	13	
RS0	37		15	16	PB4 b0
gnd	38		16	15	
gnd	39				
gnd	40				
gnd	41				
gnd	42				
+5	43	+5			
+5	44				
+5	45				
+12	46	+12			
+12	47				
+12	48				
+12	49				
N.C.	50				

Figure B4.10: TEAC Tape Deck Interface Cable

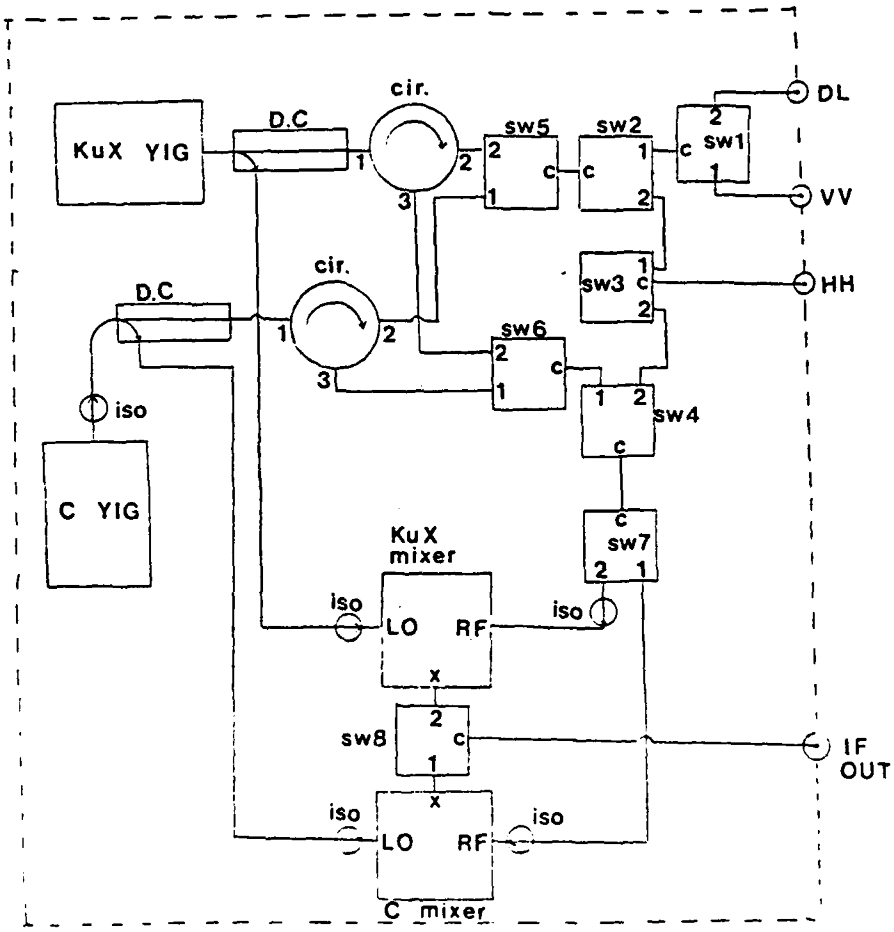
Fluke			SB 80/10 -J2	
Signal	connector #		connector #	Signal
3S D8	14	---	35	P4 B7
3S D4	B	---	37	B6
3S D2	15	---	39	B5
3S D1	S	---	41	B4
4S D8	12	---	49	B3
4S D4	N	---	42	B2
4S D2	13	---	45	B1
4S D1	P	---	43	B0
5S D8	10	---	17	P5 B7
5S D4	L	---	15	B6
5S D2	11	---	13	B5
5S D1	M	---	11	B4
LS D8	8	---	3	B3
LS D4	J	---	9	B2
LS D2	9	---	7	B1
LS D1	K	---	5	B0
Print	2	---	33	P6 B7
KHz	21	---	31	B6
DP (L)	F	---	29	B5
DP (N)	H	---	27	B4
2S D8	16	---	19	B3
2S D4	T	---	21	B2
2S D2	17	---	23	B1
2S D1	U	---	25	B0
GND	A	---	even #'s	GND

Figure B4.11: Fluke Interface Cable

Boonton			SB 80/10 - J1	
Signal	connector #		connector #	Signal
- dBm	2	---	33	P1 B7
MSD 4	4	---	35	B6
2	A	---	37	B5
1	1	---	39	B4
2SD 8	E	---	47	B3
4	D	---	45	B2
2	C	---	41	B1
1	B	---	43	BØ
3SD 8	K	---	15	P2 B7
4	J	---	13	B6
2	H	---	11	B5
1	F	---	9	B4
LSD 8	P	---	1	B3
4	N	---	3	B2
2	M	---	5	B1
1	L	---	7	BØ
encode complete	W	---	31	P3 B7
Volt mode	3	---	23	B6
$\overline{\text{OVER}}$	Z	---	27	B5
$\overline{\text{UNDER}}$	Y	---	21	B4
RANGE 8	U	---	17	B3
4	T	---	19	B2
2	S	---	29	B1
1	R	---	25	BØ
GND	5	*	even numbers	GND

*Low voltage ground isolation. Another ground must be provided.

Figure B4.12: Boonton Interface Cable



B5: RF MODULE

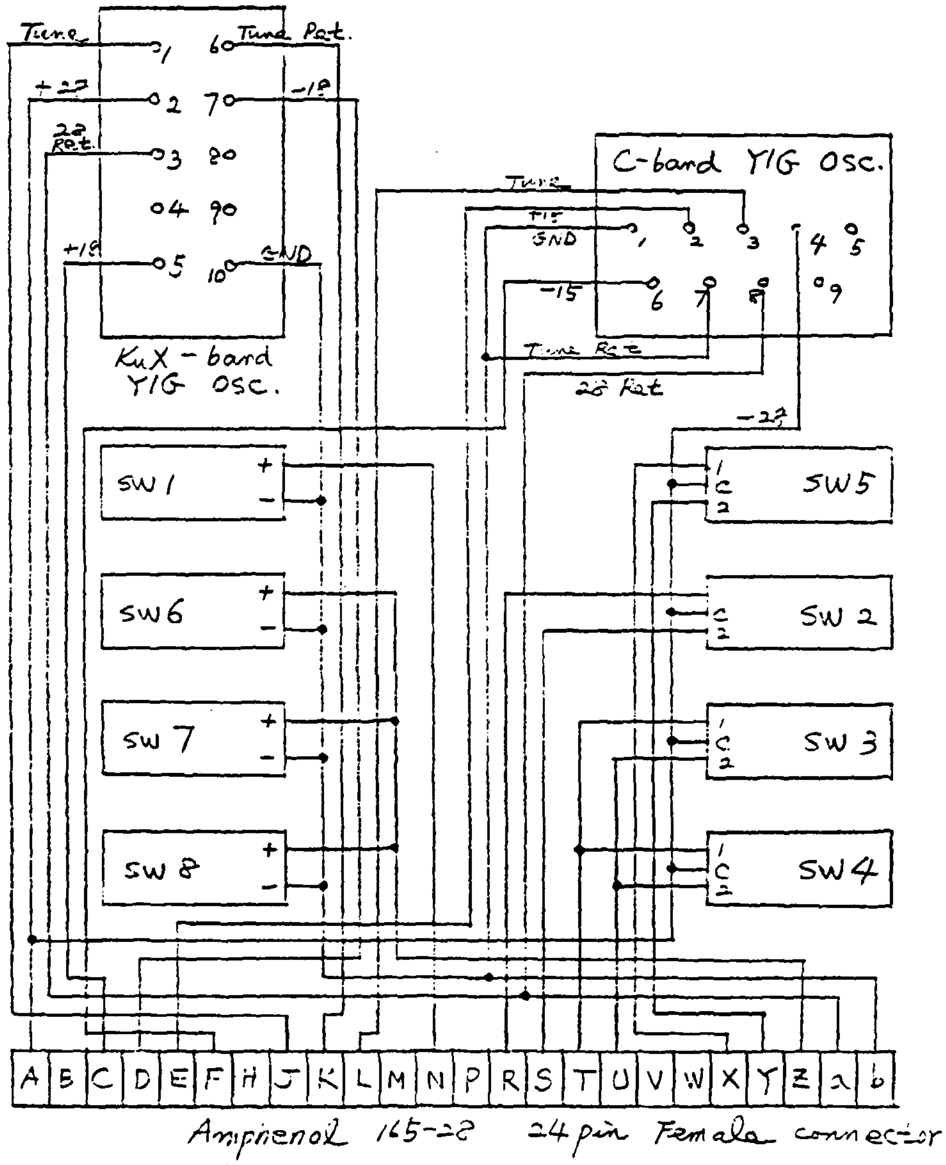


Figure B5.1: RF Module Wiring Diagram

	KuX-band					C-band				
	SW1	SW2	SW3	SW4	SW5,6,7,8	SW1	SW2	SW3	SW4	SW5,6,7,8
DL	2	1	1	1	2	2	1	1	1	1
VV	1	1	1	1	2	1	1	1	1	1
HH	1	2	1	1	2	1	2	1	1	1
VH	1	1	2	2	2	1	1	2	2	1

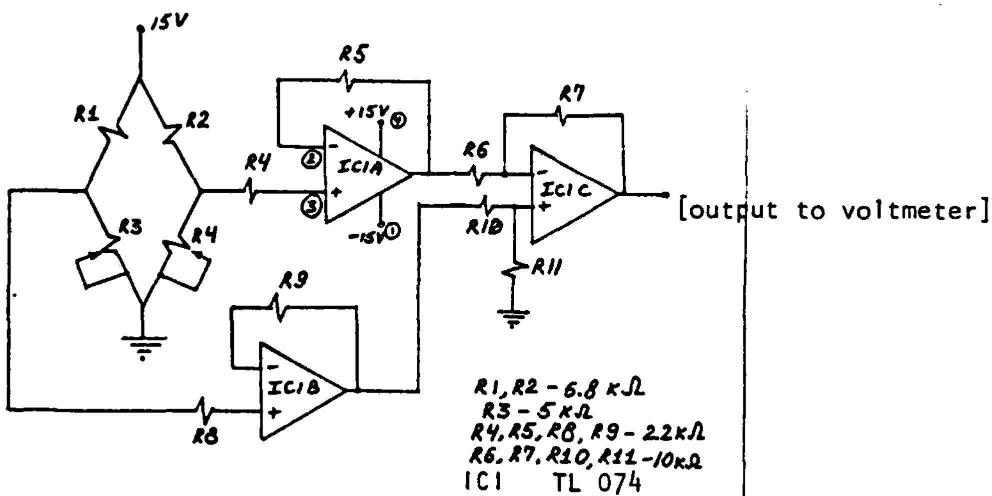
Table B5.1a: Logic Matrix for the Switch Positions

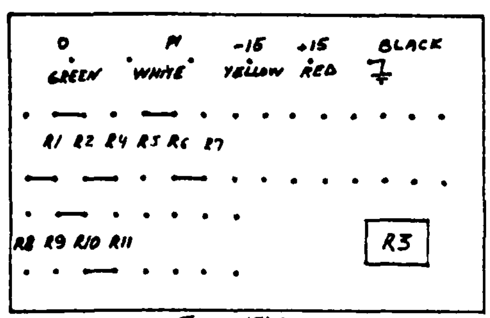
Control Connector Pin	Wiring Color Code	
A	Black	+28 V, Ku-X-YIG(#2),C-YIG(#4), SW5,2,3,4 common
B		open
C	Red	+18 V, Ku-X-YIG(#5)
D	Green	-18 V, Ku-X-YIG(#7)
E	Orange	+15 V, C-YIG(#2, red)
F	Blue	-15 V, C-YIG(#6, green)
H	White/black	open
J	Grey coax	Ku-X-YIG Tune (#1)
K	Coax shield	Ku-X-YIG Tune return (#6)
L	Orange/Black	C-YIG Tune (#3, orange)
M	Blue/Black	L-band mode control SW1 +
N	Black/White	SW1 control-DL port +
P	Red/White	open
R	Green/White	SW2 control 1
S	Blue/White	SW2 control 2
T	Black/Red	SW3,4 control 1
U	White/Red	SW3,4 control 2
V	Orange/Red	L-band mode control SW2 +
W	Blue/Red	L-band mode control SW3,4 +
X	Red/Green	SW5 control 1
Y	Orange/Green	SW5 control 2
Z	Black/White/Red	SW6,7,8 control +
a	White/Black/Red	+28 V return, Ku-X-YIG#3, C-YIG#8
b	Red/Black/White Green/Black/White	Ground to SW1 gnd, SW6,7,8 -, Ku-X-YIG#10, C-YIG#1,#7

Table B5.1b: RF Module Wiring List

Connector Letter	Volts or Signal	Required By Module PS	RM	DAM	Wire Gauge	Color Code
A	+28	x	x	x	18	Red
B	+18	x	x		18	Blue
C	-18	x	x		18	Gray
D	+15	x	x	x	18	Green
E	-15	x	x	x	18	Violet
F	+12	x		x	18	Brown
H	-12	x		x	18	White
J	+5	x	x	x	18	Yellow
K	-5	x		x	18	Orange
L	LSB1		x	x	22	Yellow
M	LSB2		x	x	22	Yellow
N	MSB2		x	x	22	Yellow
P	MSB1		x	x	22	Yellow
R	GND	x	x	x	16	Black

Figure B6: Power Supply Multiconductor Cable





Top VIEW

Figure B7: Angle Encoder (Separate box)

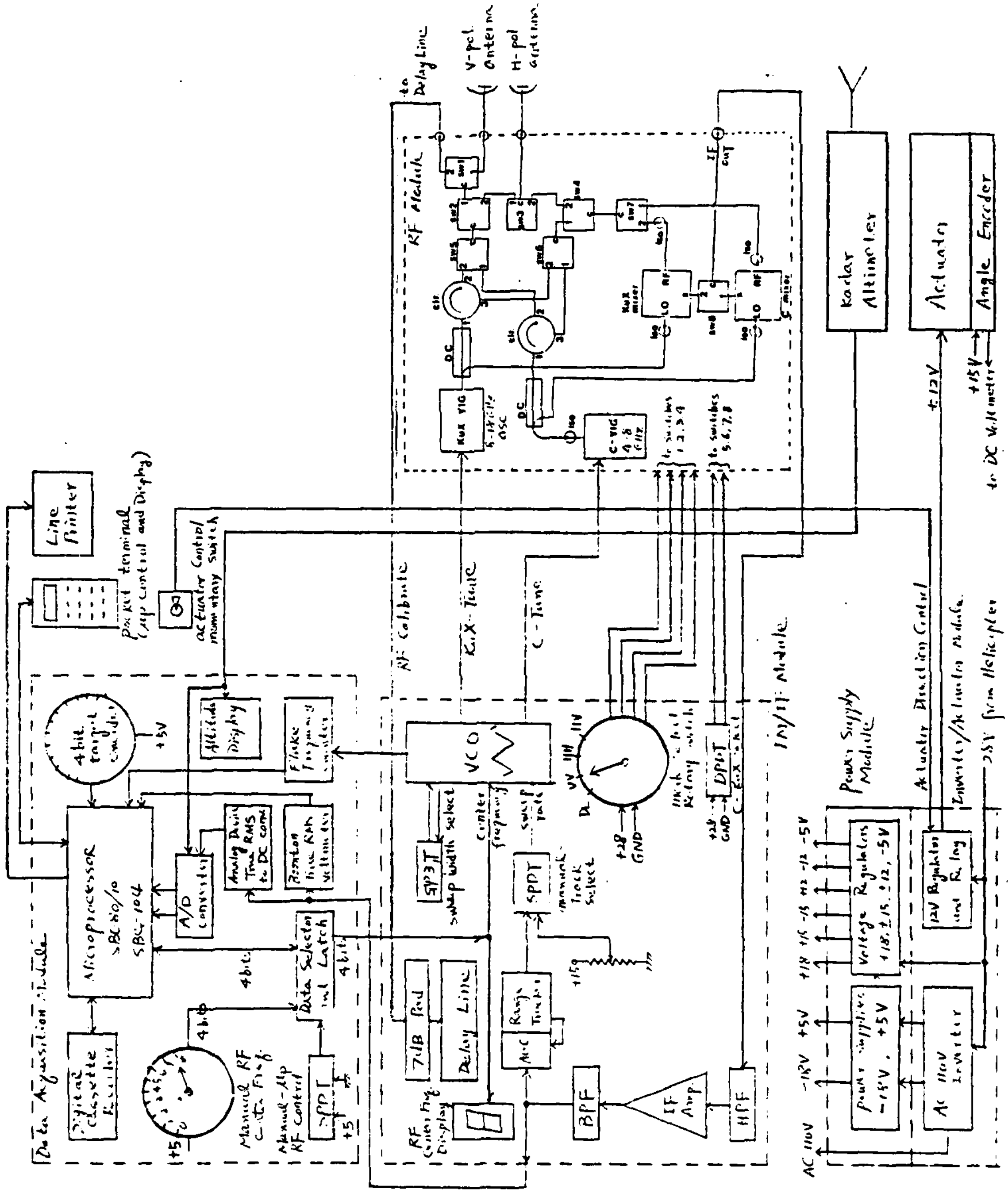


Figure B8: System Block Diagram

TABLE B8

System Control Signal Cables

Cable Name	Description	Connector Description
+28 VDC IN	Aircraft source to INV/ACT Mod.	2pin-Amp
Actuator	Actuator to INV/ACT Mod.	2pin-Amp
Actuator Control	Remote switch to INV/ACT Mod.	3pin-Audio
115 VAC	Source located at INV/ACT Mod. Required by PS, IF/FM, and DA Mods.	AC
DC Power	Links to +28 VDC at INV/ACT Mod. to PS, IF/FM, and DA Mods.	3pin-Audio 14pin-Amp
RF	IF/FM Mod to RF Mod.	28pin-Amp
IF IN	IF/FM Mod. to RF Mod.	BNC
IF OUT	RF Mod. to 50Ω Term. at DA Mod. (Boonton)	BNC
FM	IF/FM Mod. to DA Mod. (Fluke)	BNC
RMS	At DA Mod. Links RMS to Boonton	BNC
Altimeter	DA Mod. to Altimeter	3pin-Audio

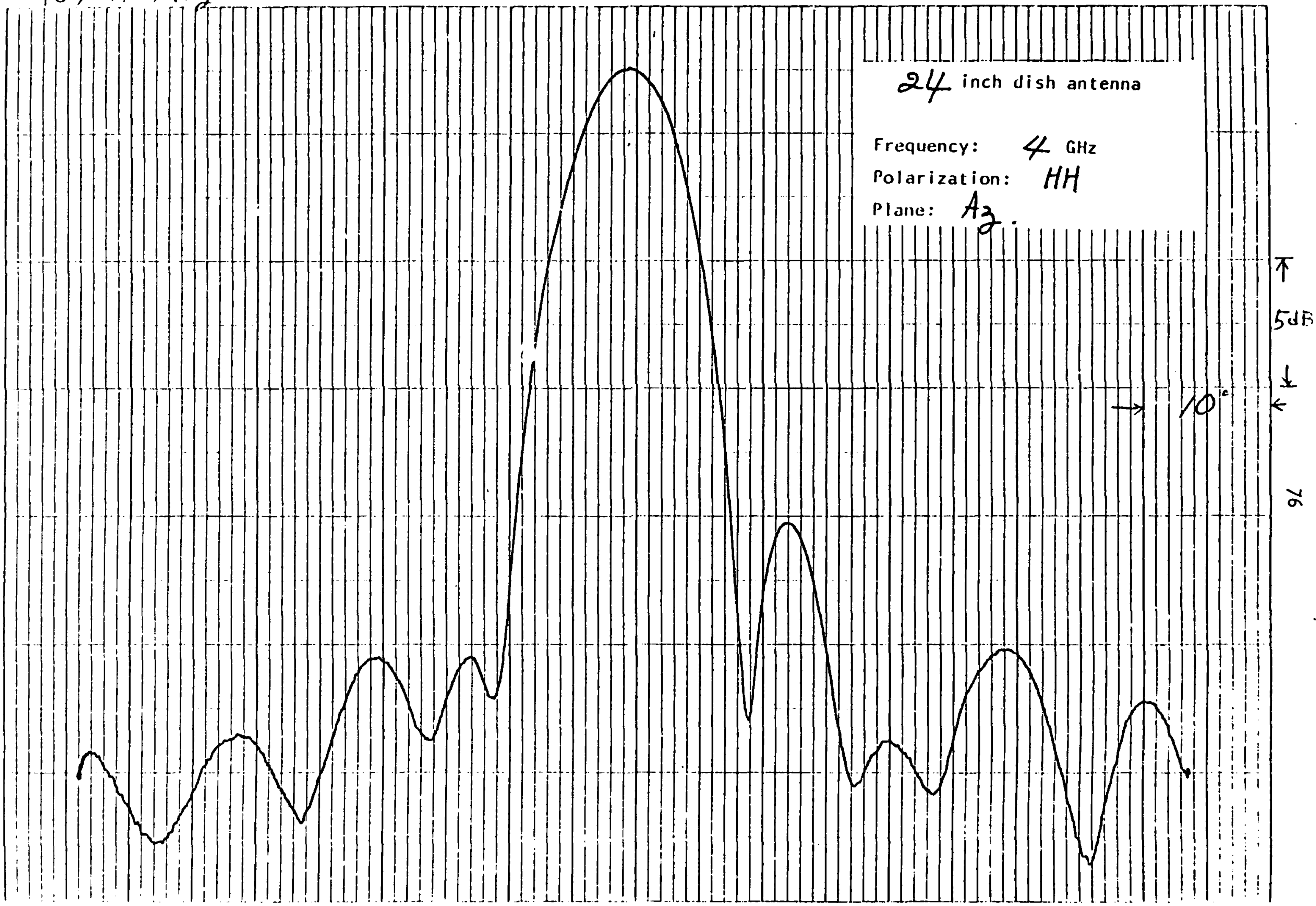
APPENDIX C

TWO-WAY EFFECTIVE BEAMWIDTHS IN DEGREES FOR HELOSCAT SYSTEM

	VV-polarization (18" dish)		HH-polarization (24" dish)		VH-polarization	
<freq.>	β_e	β_a	β_e	β_a	β_e	β_a
1.5 GHz	15.9	14.2	9.1	9.8	11.4	11.5
4.4	8.2	7.4	5.8	6.1	6.8	6.8
4.8	7.6	6.9	5.4	5.8	6.3	6.3
5.2	7.0	6.3	5.1	5.3	5.9	5.9
5.6	6.5	6.0	4.7	5.1	5.4	5.5
6.0	6.2	5.4	4.4	4.7	5.1	5.1
6.4	5.2	5.2	4.2	4.4	4.7	4.9
6.8	5.0	4.9	3.9	4.2	4.4	4.5
7.2	4.9	4.5	3.7	3.9	4.2	4.3
7.6	4.7	4.3	3.5	3.7	4.1	4.0
8.6	3.9	3.7	3.0	3.3	3.5	3.5
9.6	3.7	3.4	2.7	2.9	3.2	3.2
10.6	3.5	3.0	2.5	2.7	2.9	2.9
11.6	3.0	2.8	2.3	2.5	2.6	2.7
12.6	2.9	2.5	2.1	2.4	2.5	2.5
13.6	2.9	2.4	1.9	2.4	2.3	2.5
14.6	2.8	2.4	1.8	2.3	2.1	2.4
15.6	2.7	2.1	1.7	2.3	2.0	2.3
16.6	2.4	1.9	1.6	2.1	1.8	2.0

24"

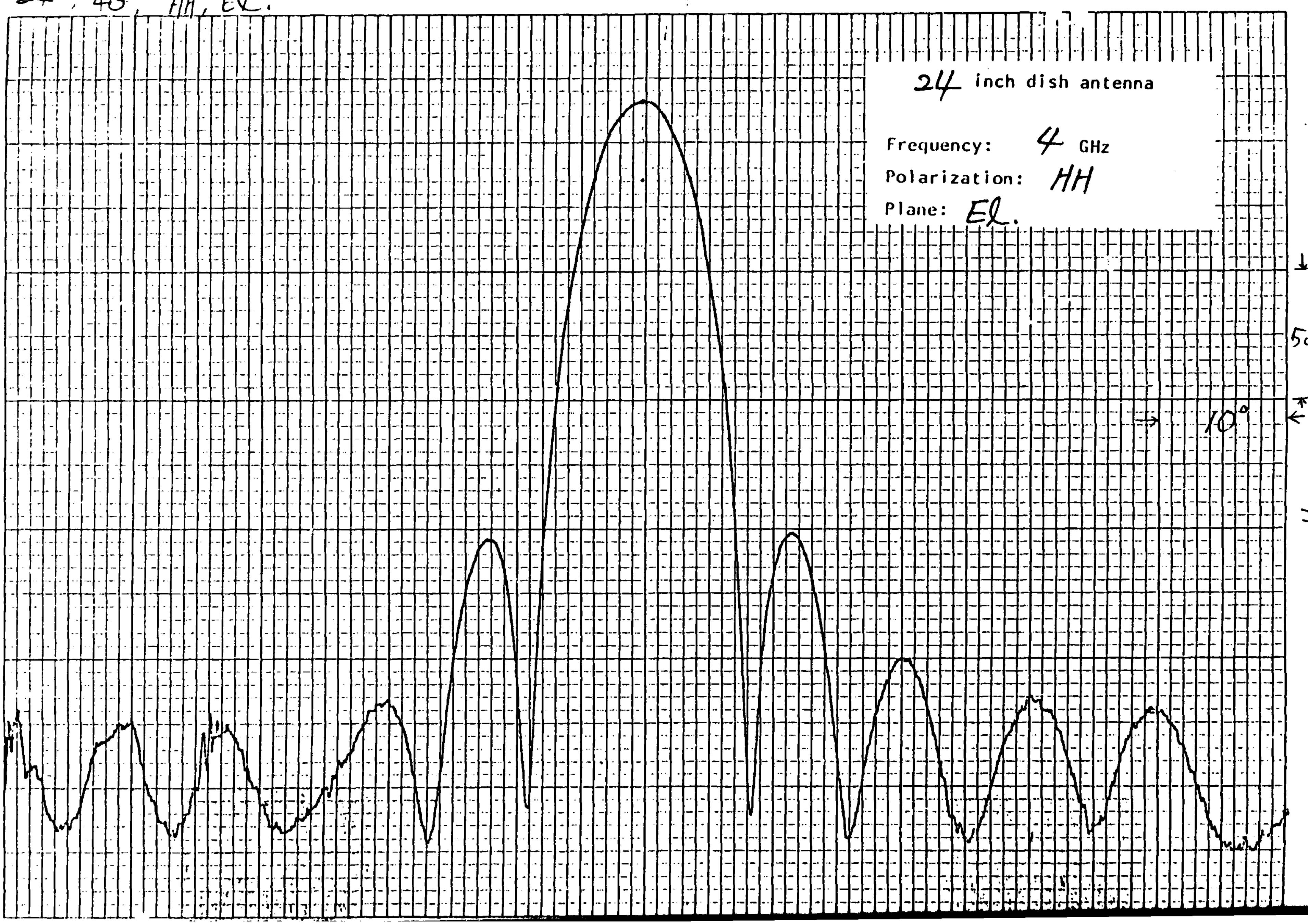
4G, HH, Az



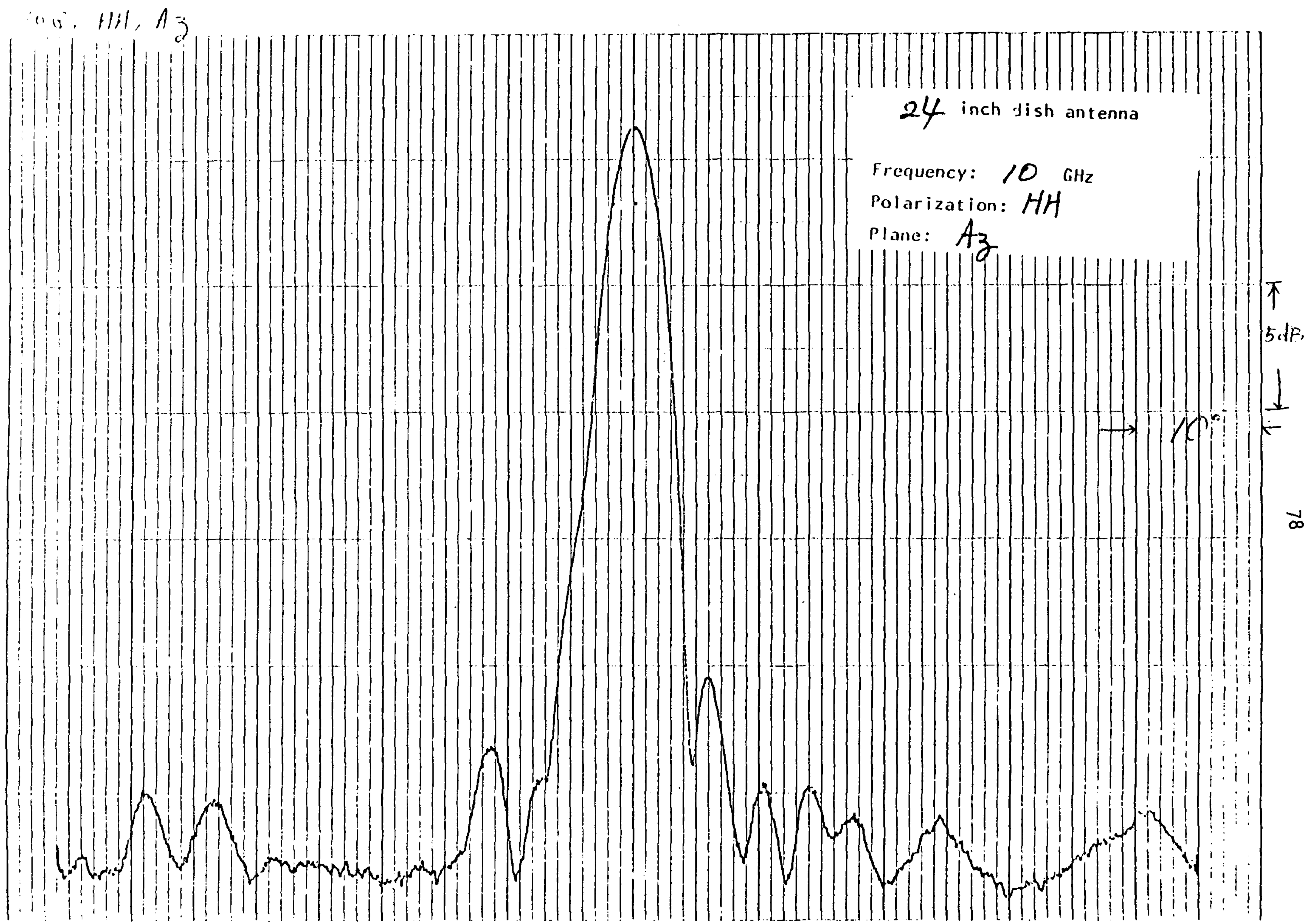
24 inch dish antenna
Frequency: 4 GHz
Polarization: HH
Plane: Az.
5dB
10°

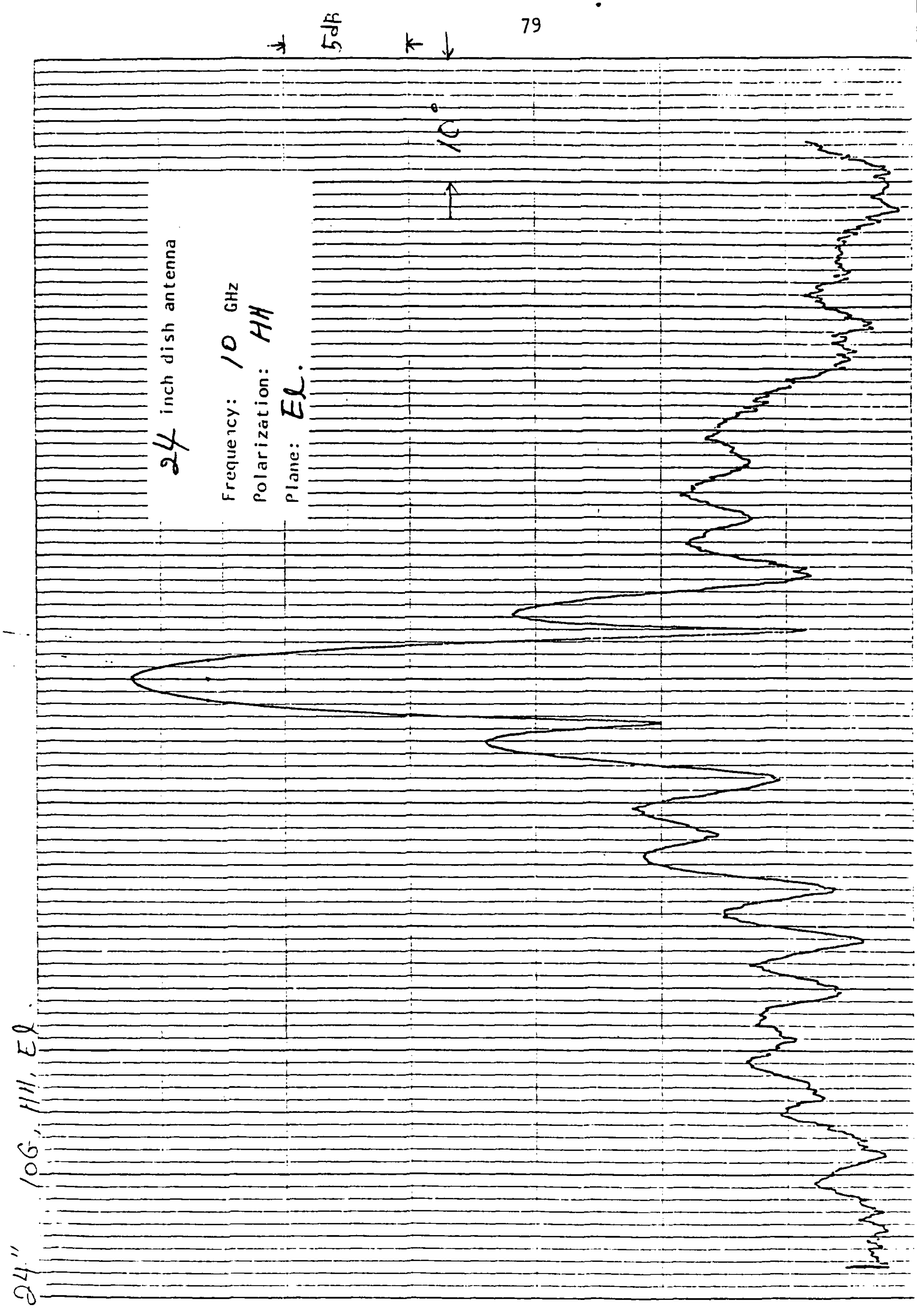
46 0782

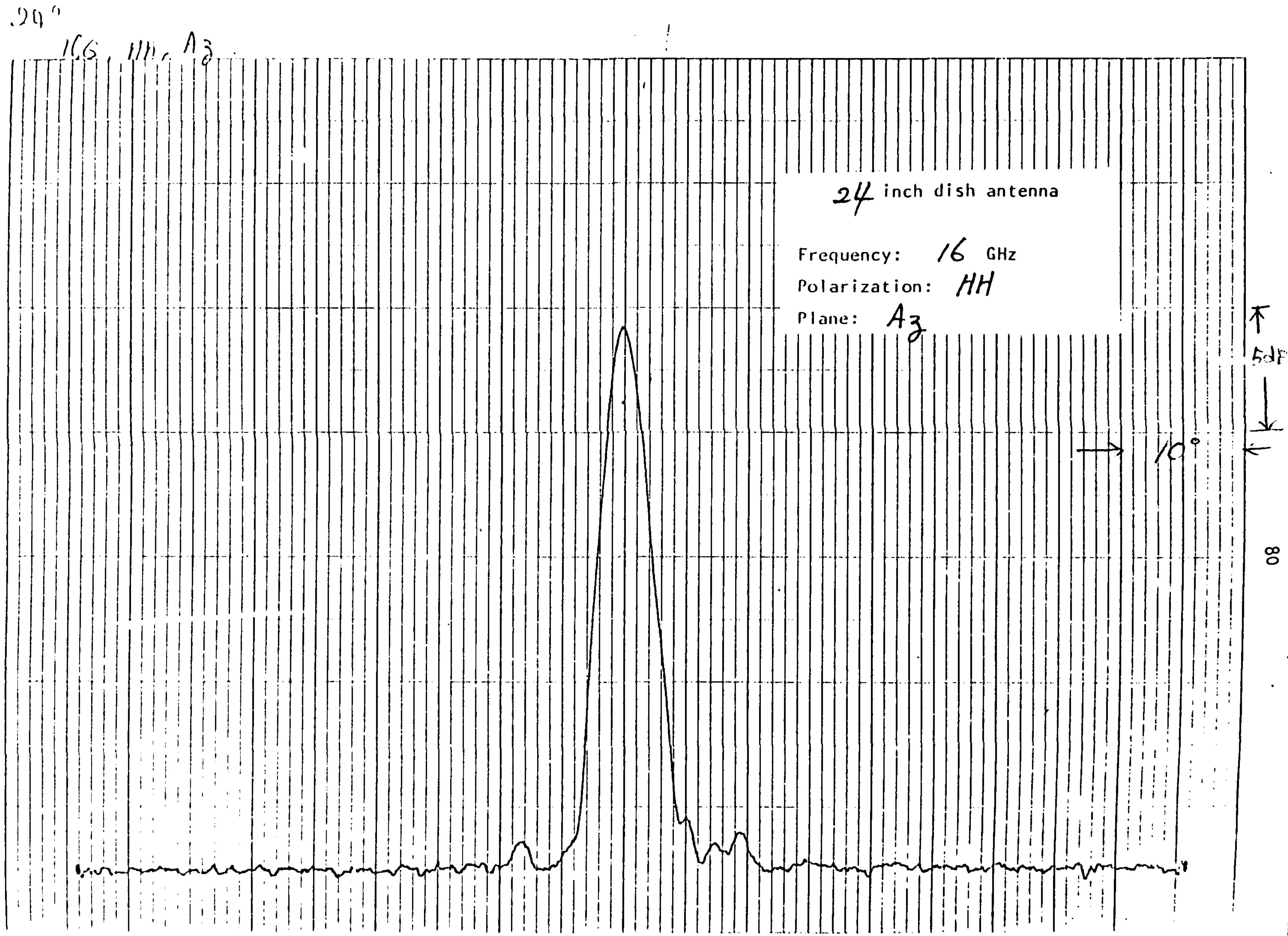
24", 4G, HH, El.



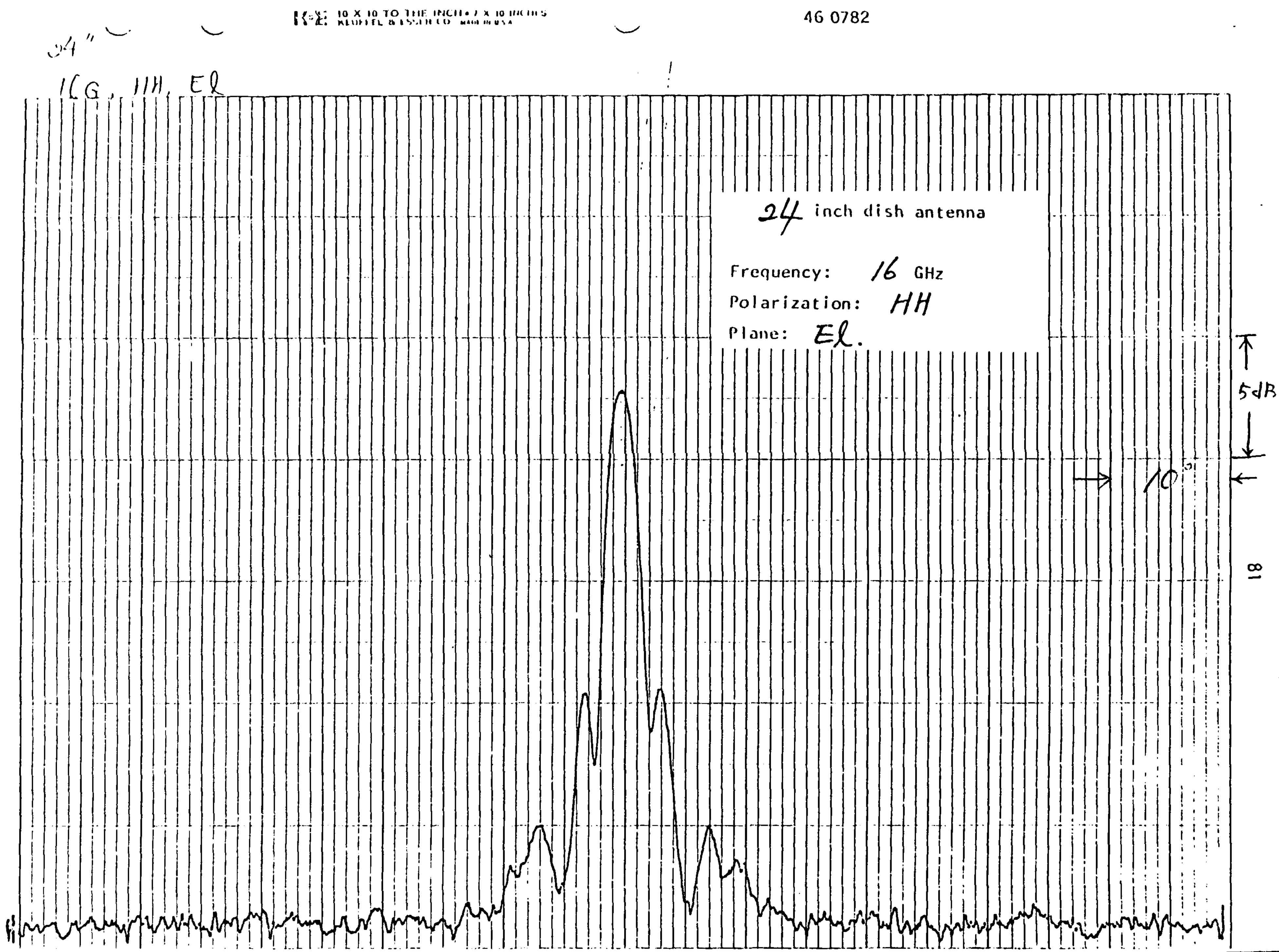
4G 0782


10 GHz, HH, Az
24 inch dish antenna
Frequency: 10 GHz
Polarization: HH
Plane: Az
5 dB
10°

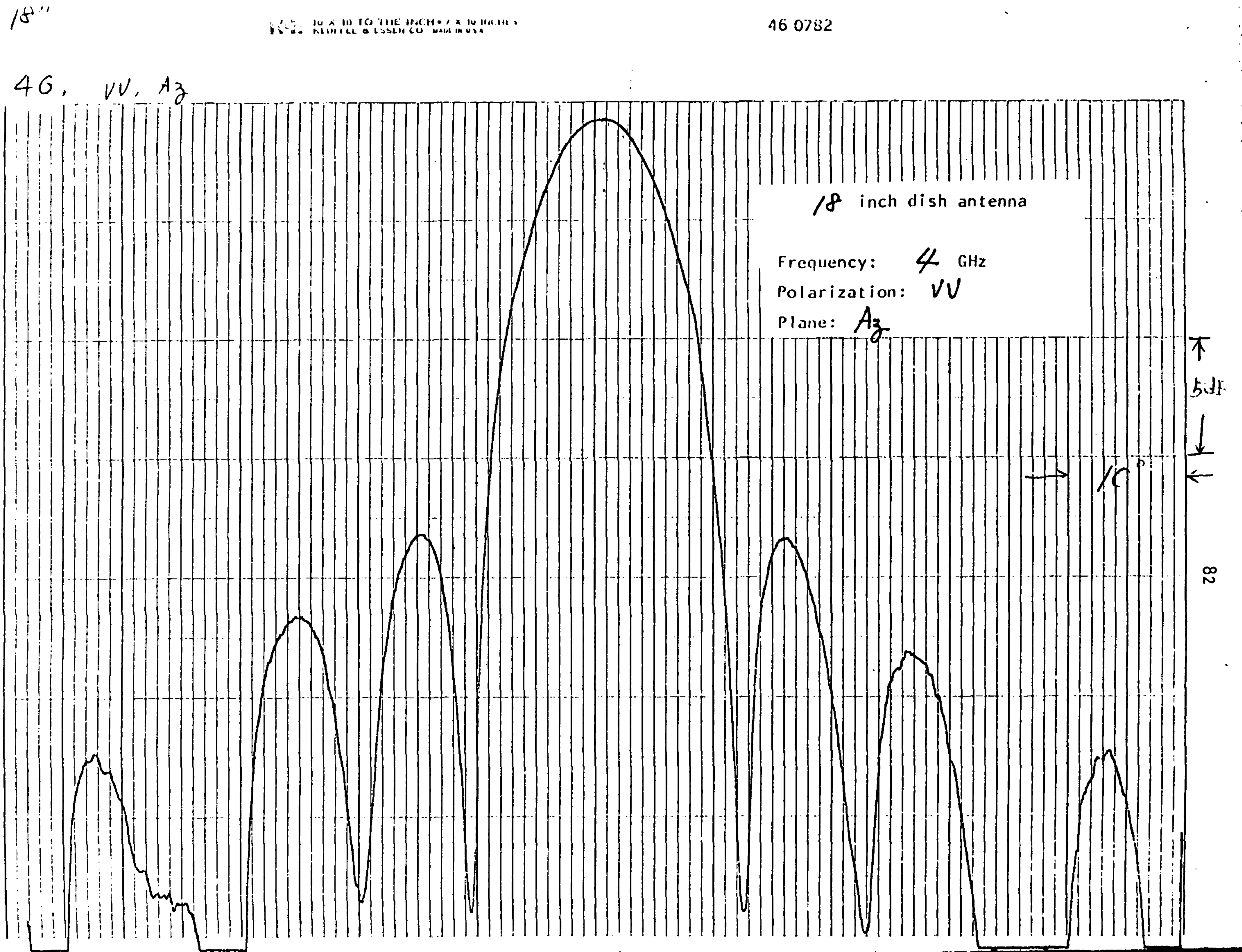

5dB
10°
24 inch dish antenna
Frequency: 10 GHz
Polarization: HH
Plane: EL.
24" 10G, HH, El

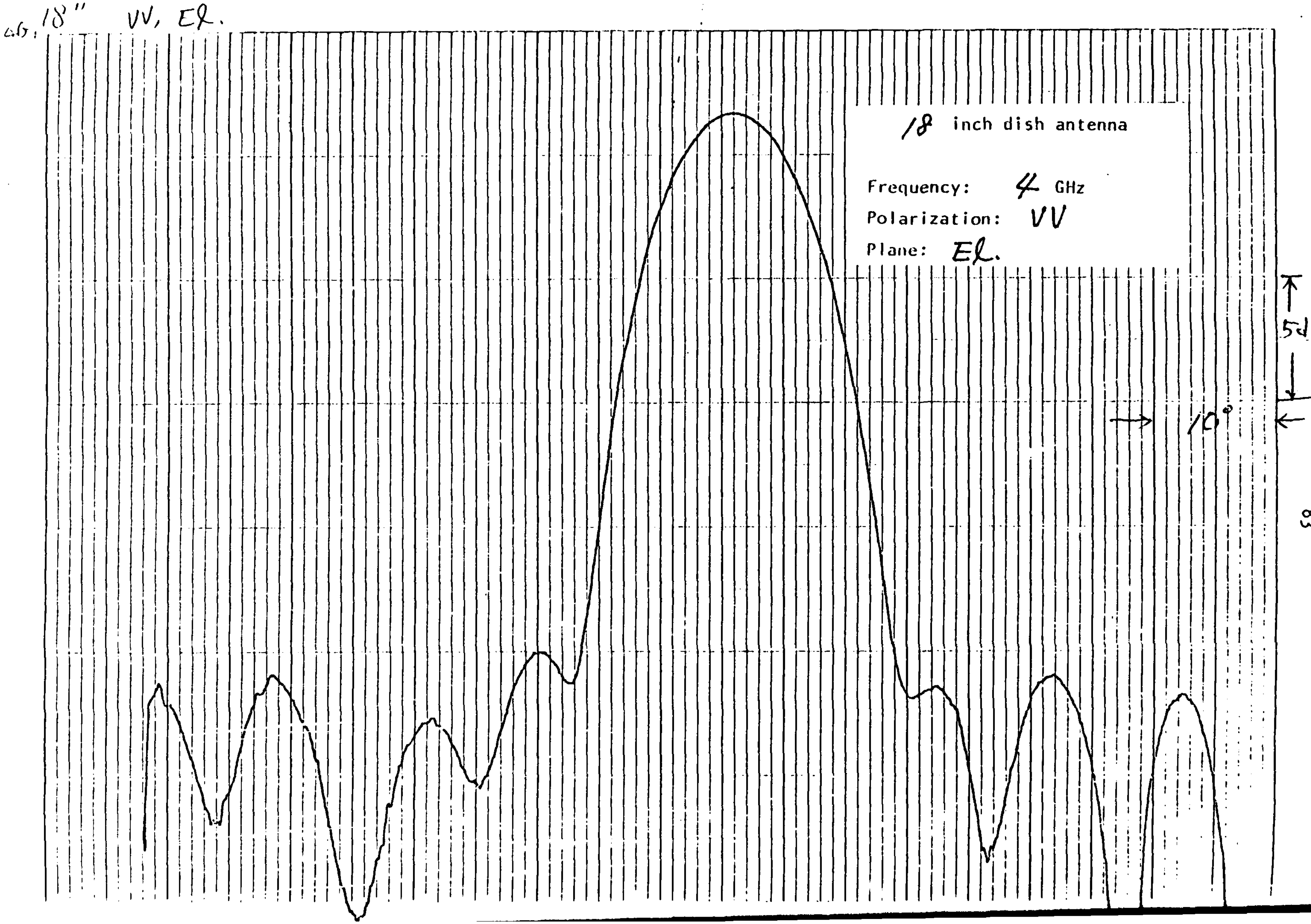


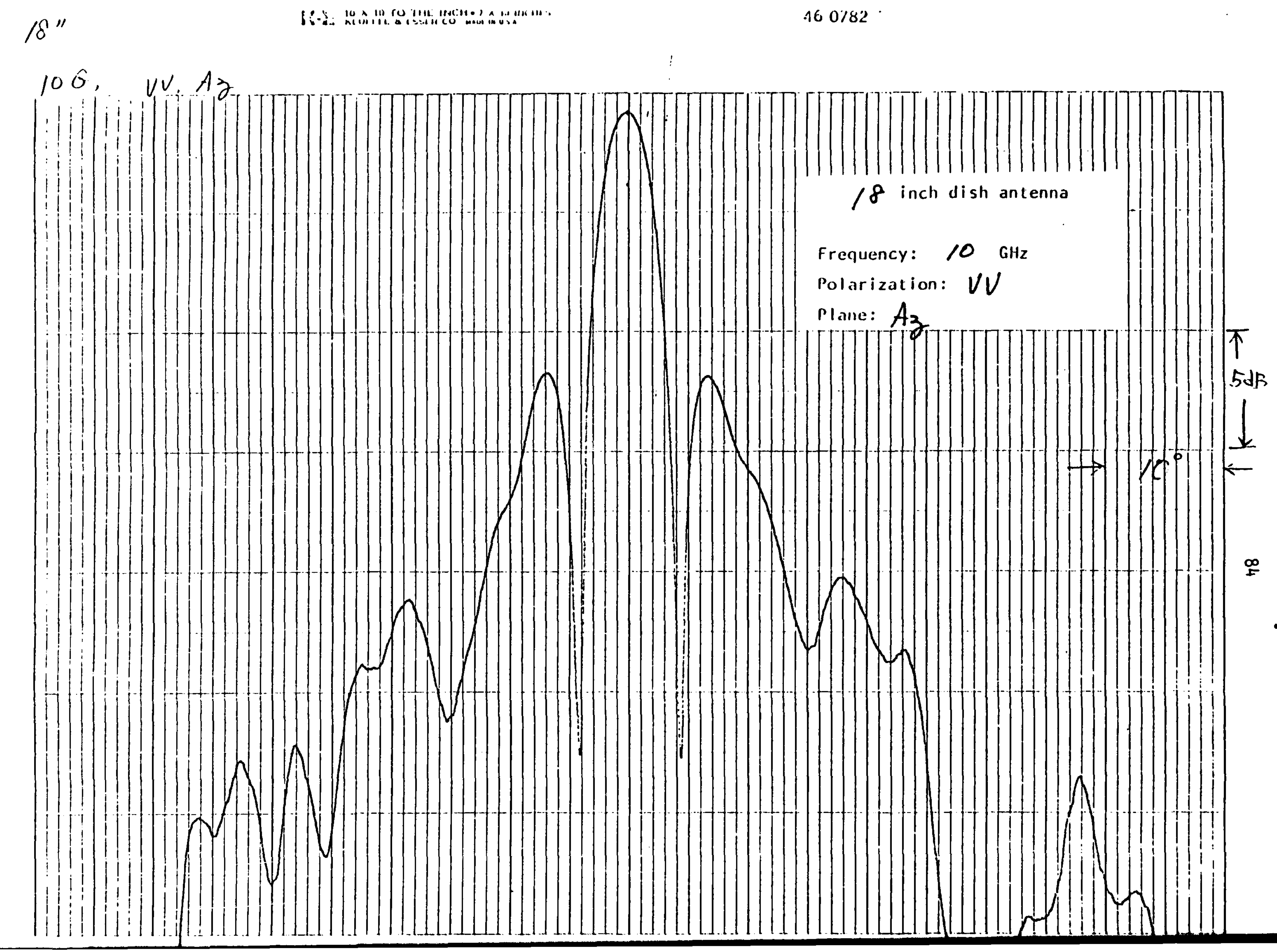
.90°
16, HH, Az
24 inch dish antenna
Frequency: 16 GHz
Polarization: HH
Plane: Az
5dB
10°

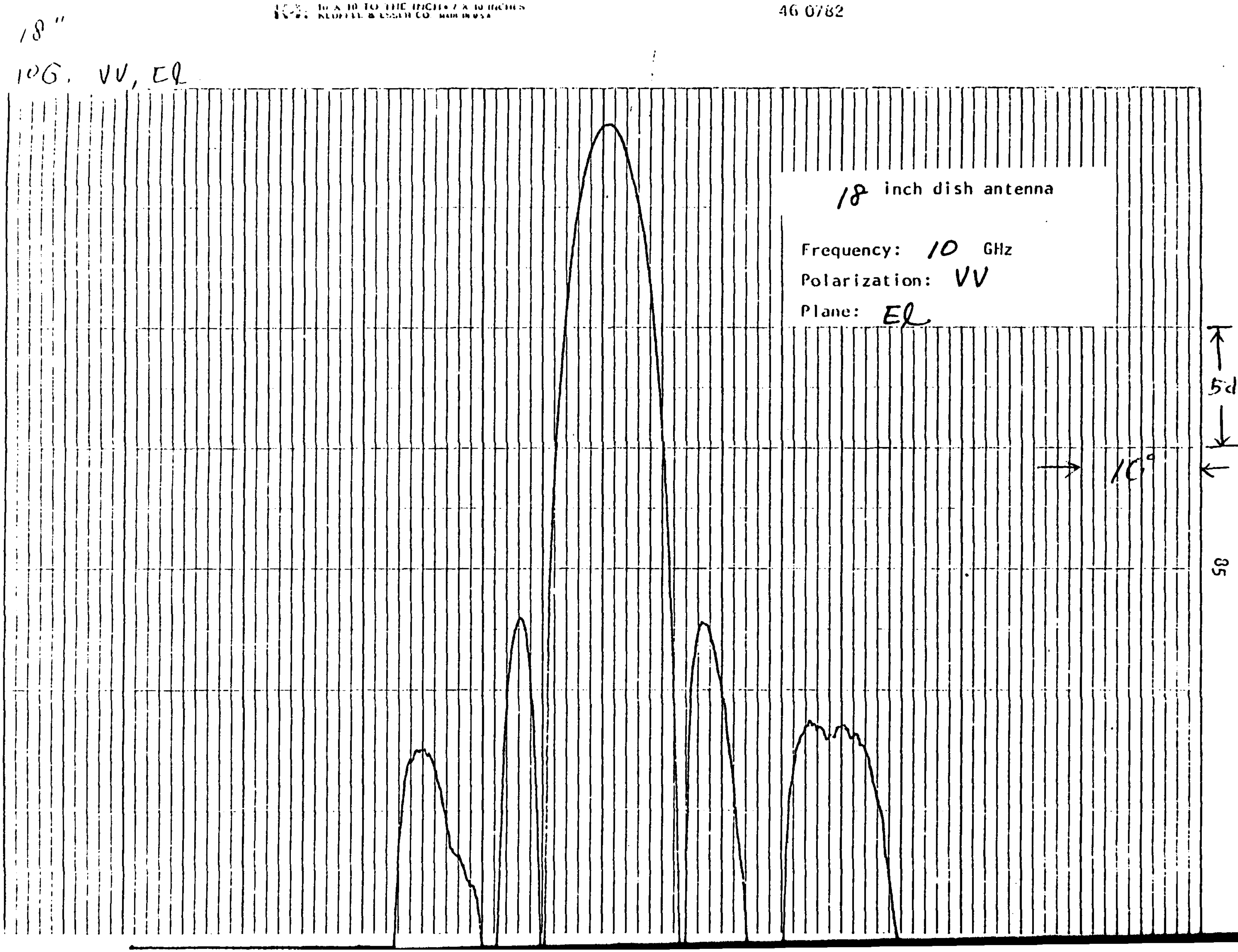


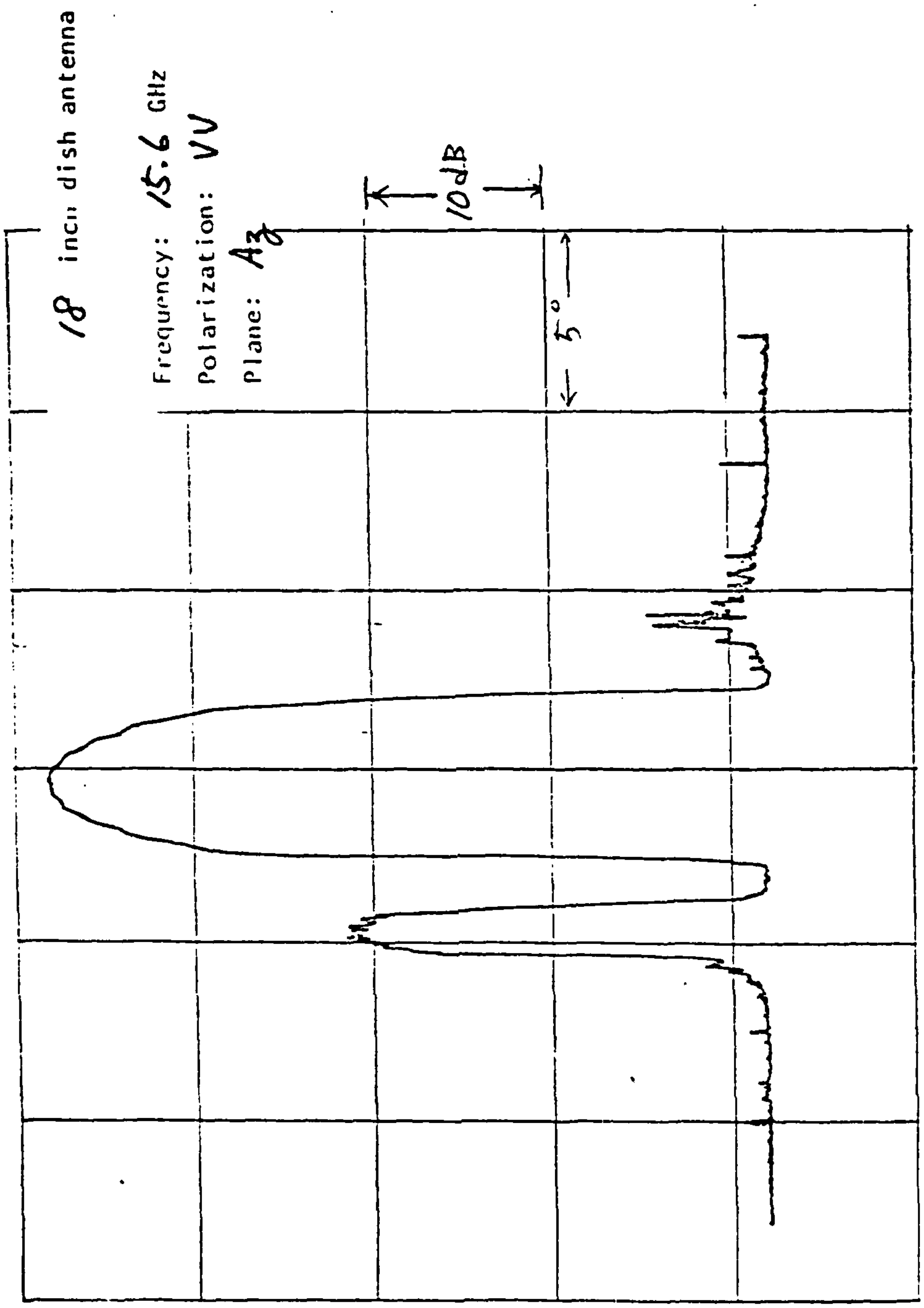
K&E 10 X 10 TO THE INCH • 7 X 10 INCHES KEUFFEL & ESSER CO.
46 0782
24"
16G, HH, El
24 inch dish antenna
Frequency: 16 GHz
Polarization: HH
Plane: El.
5dB
10°


18''
10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN USA
46 0782
4G, VV, Az
18 inch dish antenna
Frequency: 4 GHz
Polarization: VV
Plane: Az
5dB
10°


ab, 18" VV, El.
18 inch dish antenna
Frequency: 4 GHz
Polarization: VV
Plane: El.
5dB
10°

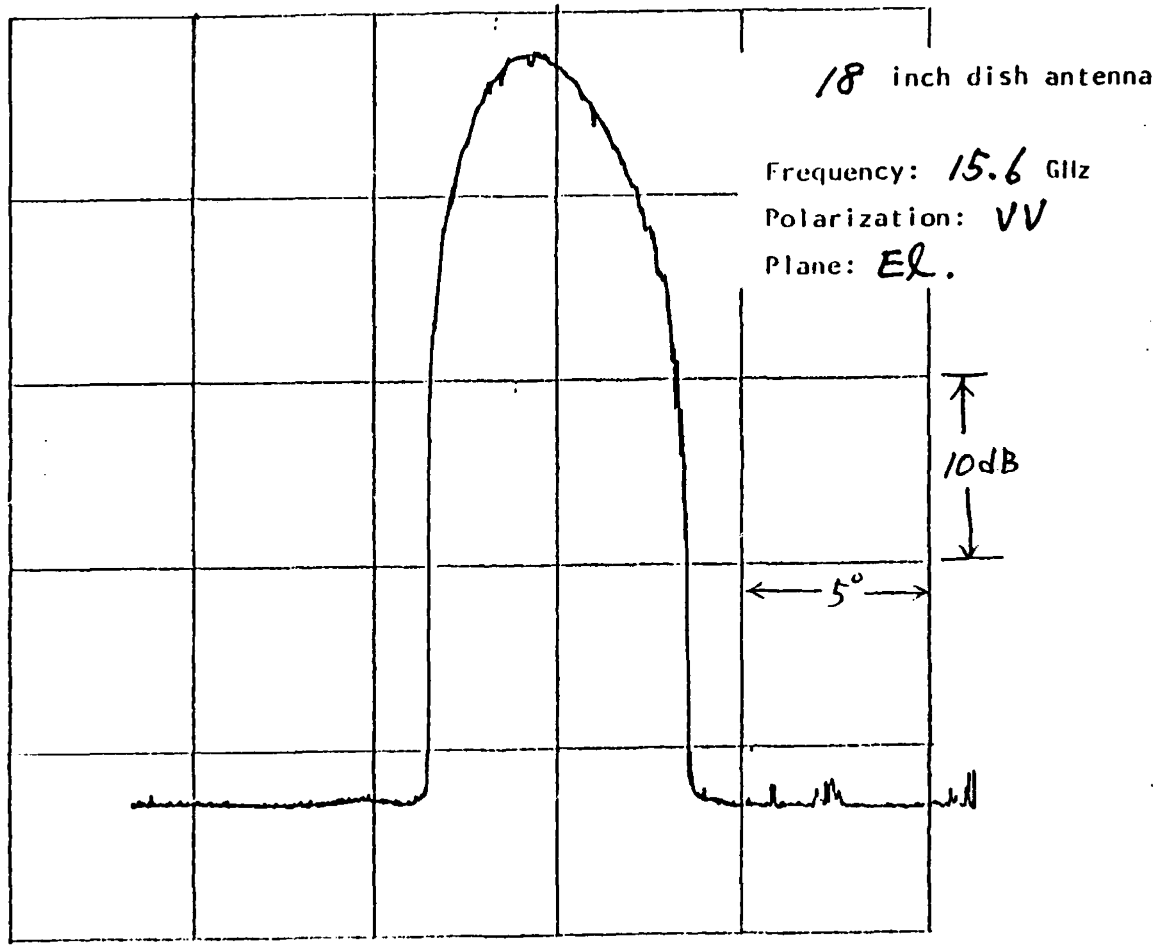

18"
10 G, VV, Az
K&E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 0782
18 inch dish antenna
Frequency: 10 GHz
Polarization: VV
Plane: Az
5dB
10°


18"
10G, VV, El
46 0782
18 inch dish antenna
Frequency: 10 GHz
Polarization: VV
Plane: El
5dB
10°

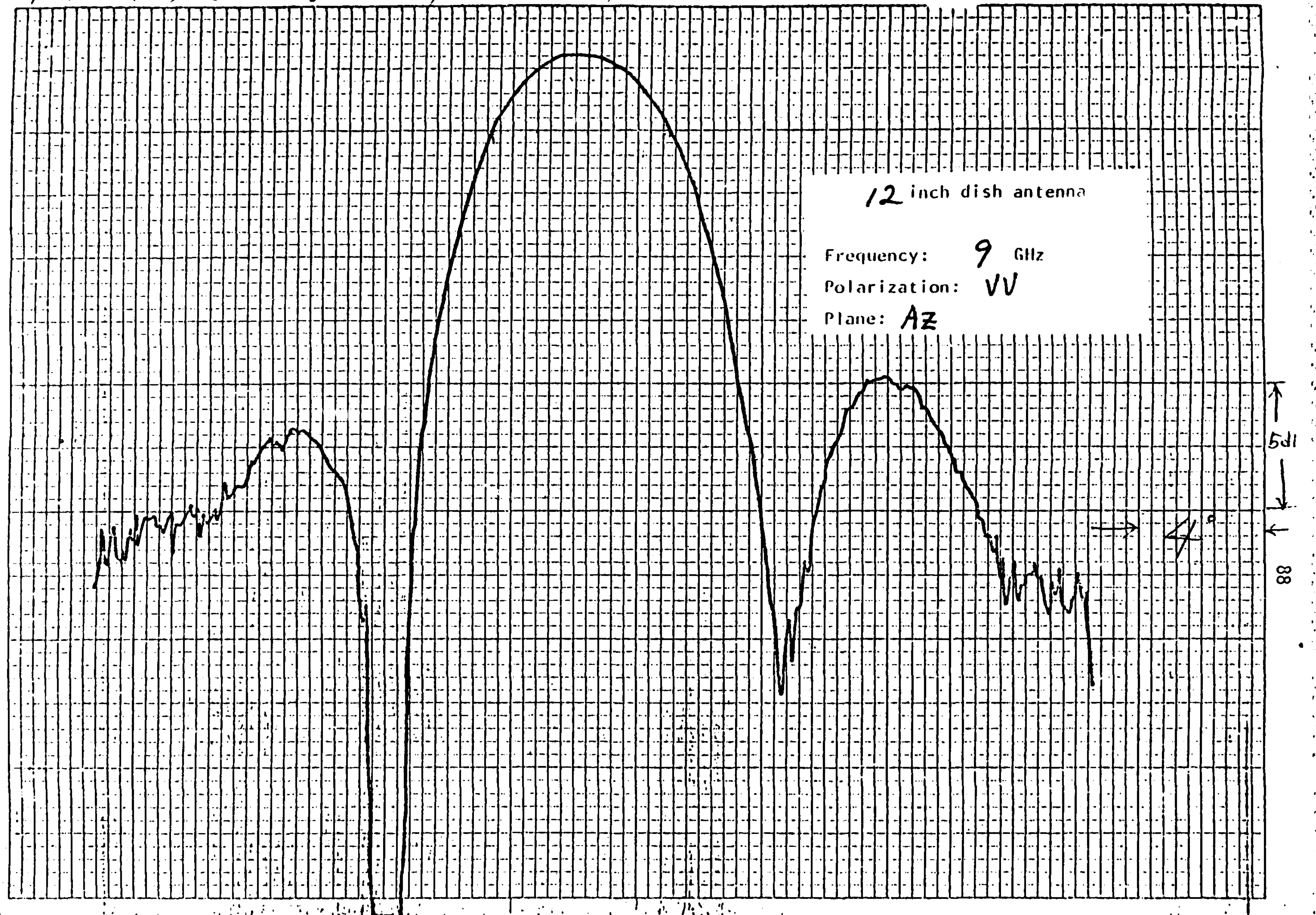

18 inch dish antenna
Frequency: 15.6 GHz
Polarization: VV
Plane: Az
10dB
5°

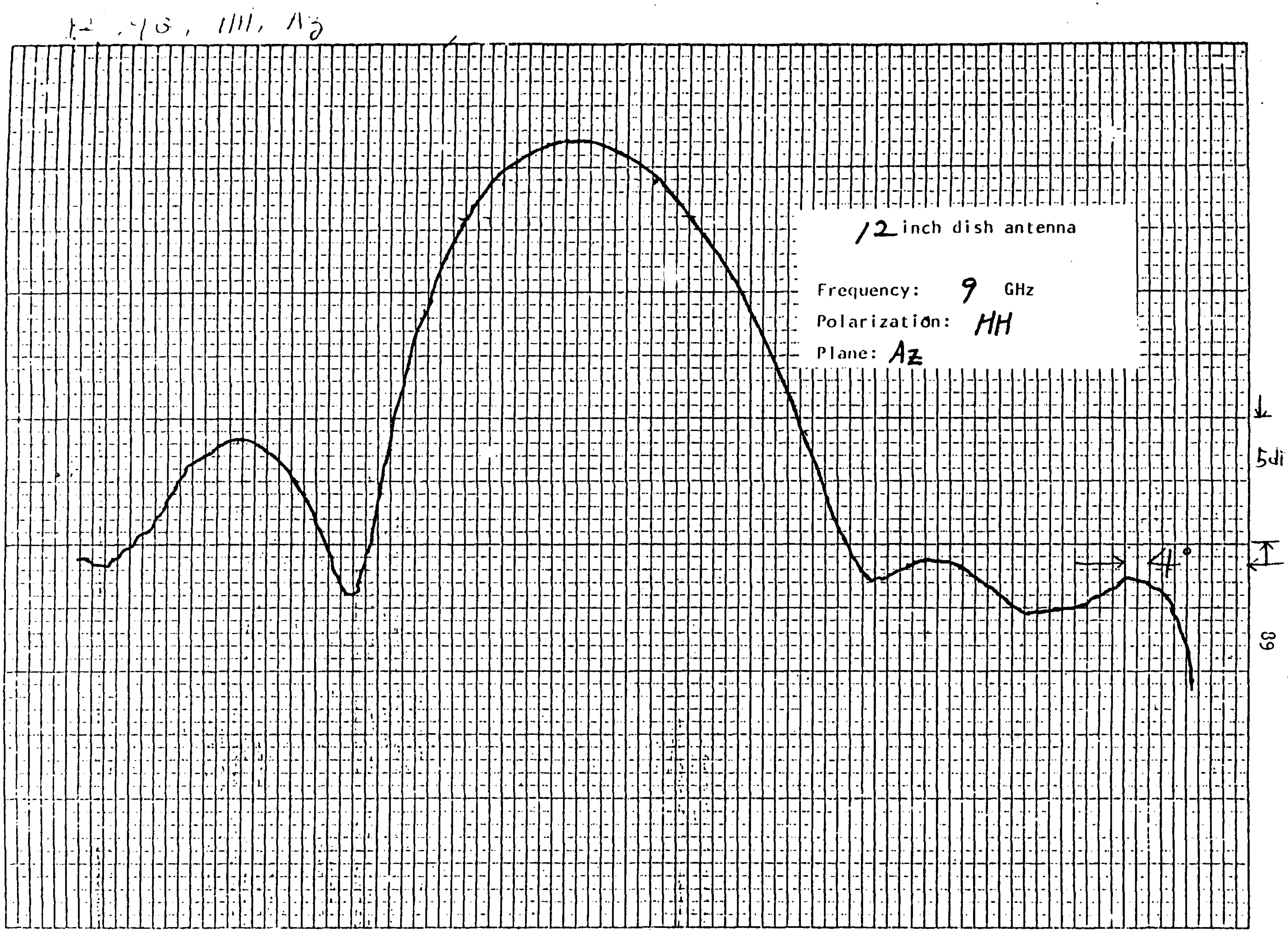
18", 15.6G, VV, Az

15.6G, VV, El.

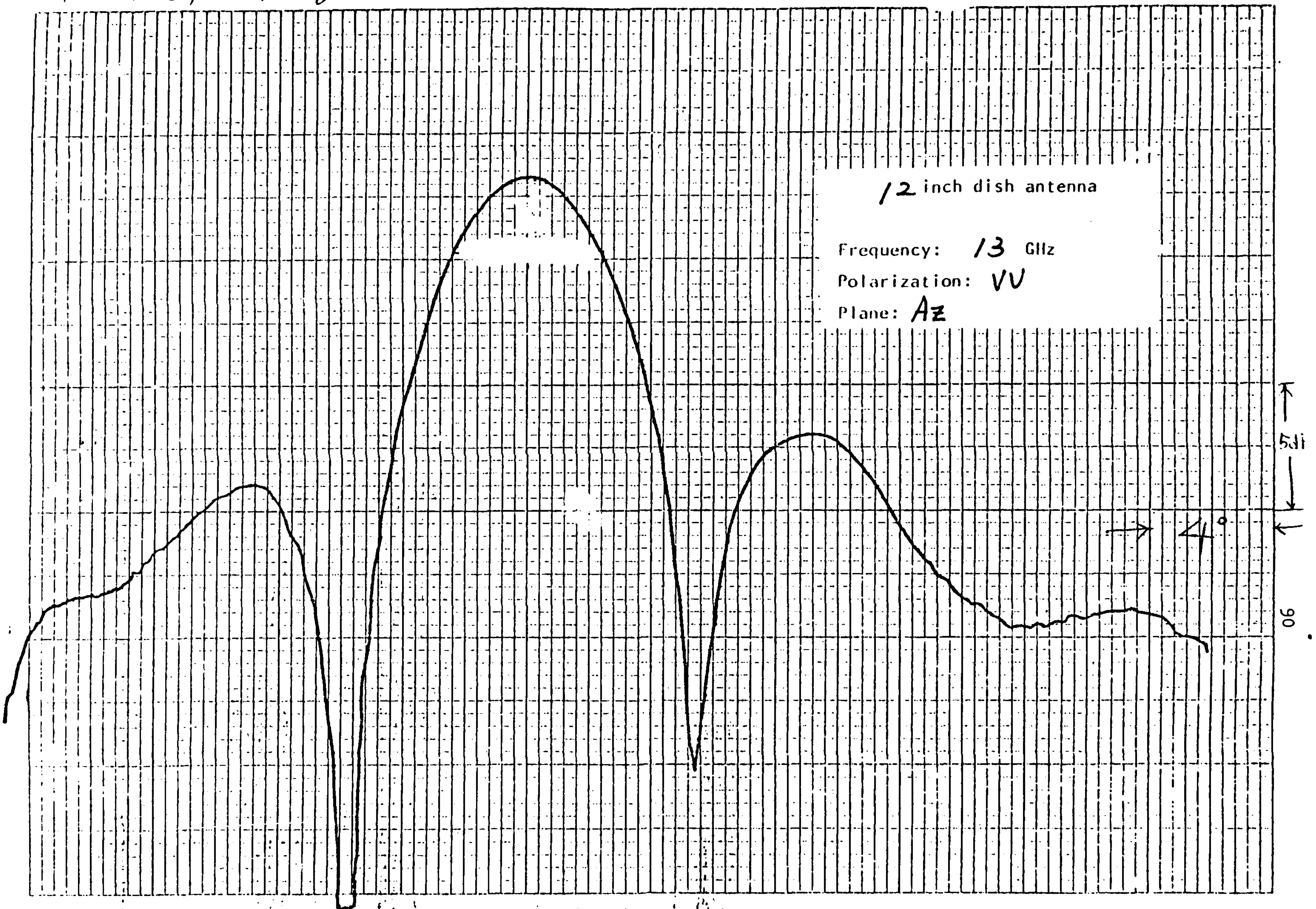

18 inch dish antenna
Frequency: 15.6 GHz
Polarization: VV
Plane: El.
10dB
5°

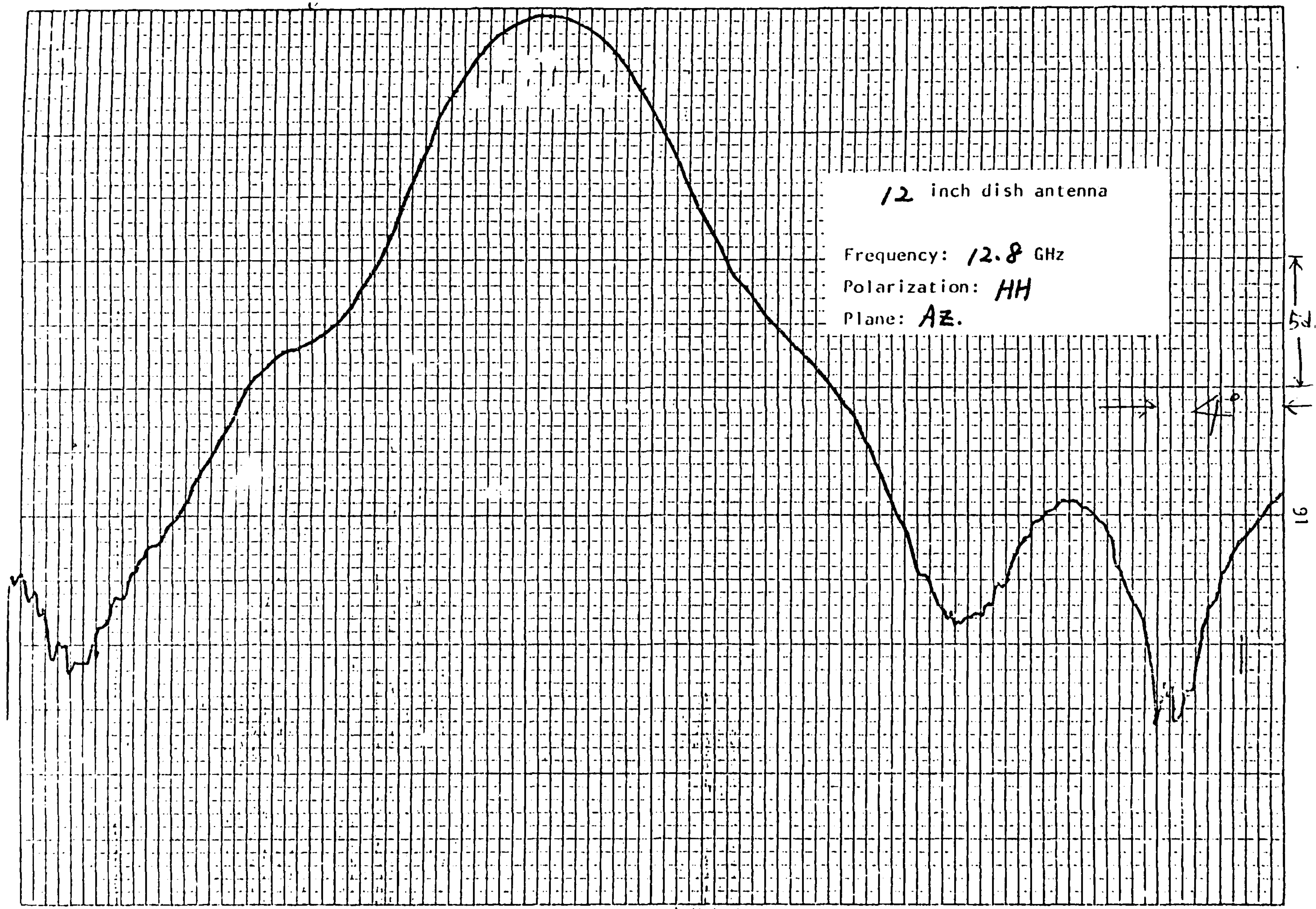
12" 9G, VV, Az. 4°/inch. 5 dB/inch




12 inch dish antenna
Frequency: 9 GHz
Polarization: HH
Plane: Az
5 dB
4°

12" 13G, VV, Az


12 inch dish antenna
Frequency: 13 GHz
Polarization: VV
Plane: Az
5dB
4°
90


12 inch dish antenna
Frequency: 12.8 GHz
Polarization: HH
Plane: Az.
5d
4°

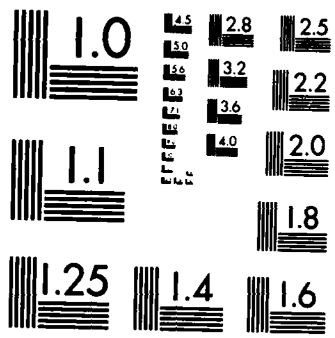
AD-A125 796 HELICOPTER-BORNE SCATTEROMETER(U) KANSAS UNIV/CENTER FOR RESEARCH INC LAWRENCE REMOTE SENSING LAB R G ONSTOTT ET AL. OCT 82 CRINC/RSL-TR-331-24 2/2

UNCLASSIFIED N00014-76-C-1105 F/G 17/9 NL

END

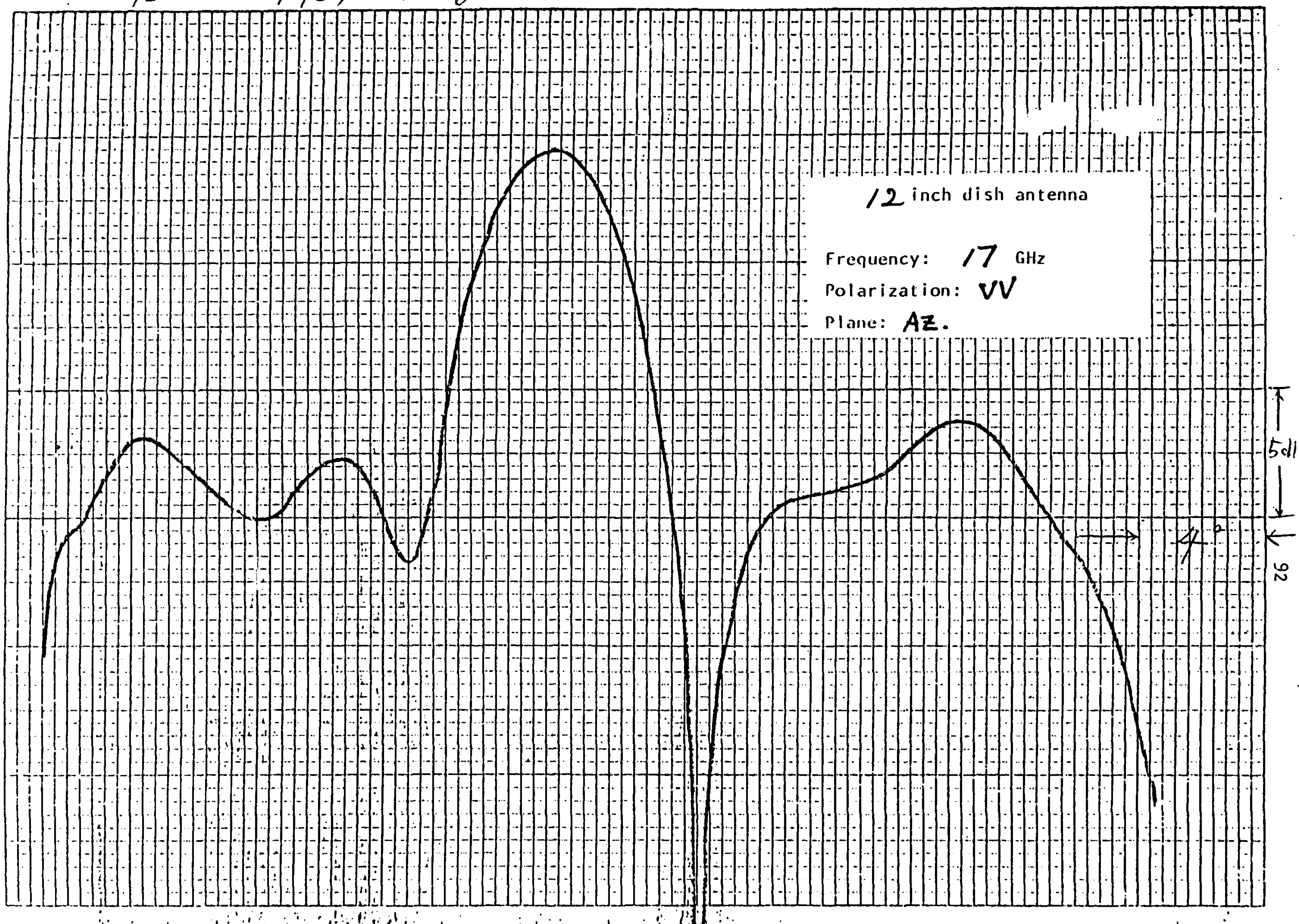
FILMED

DTIC

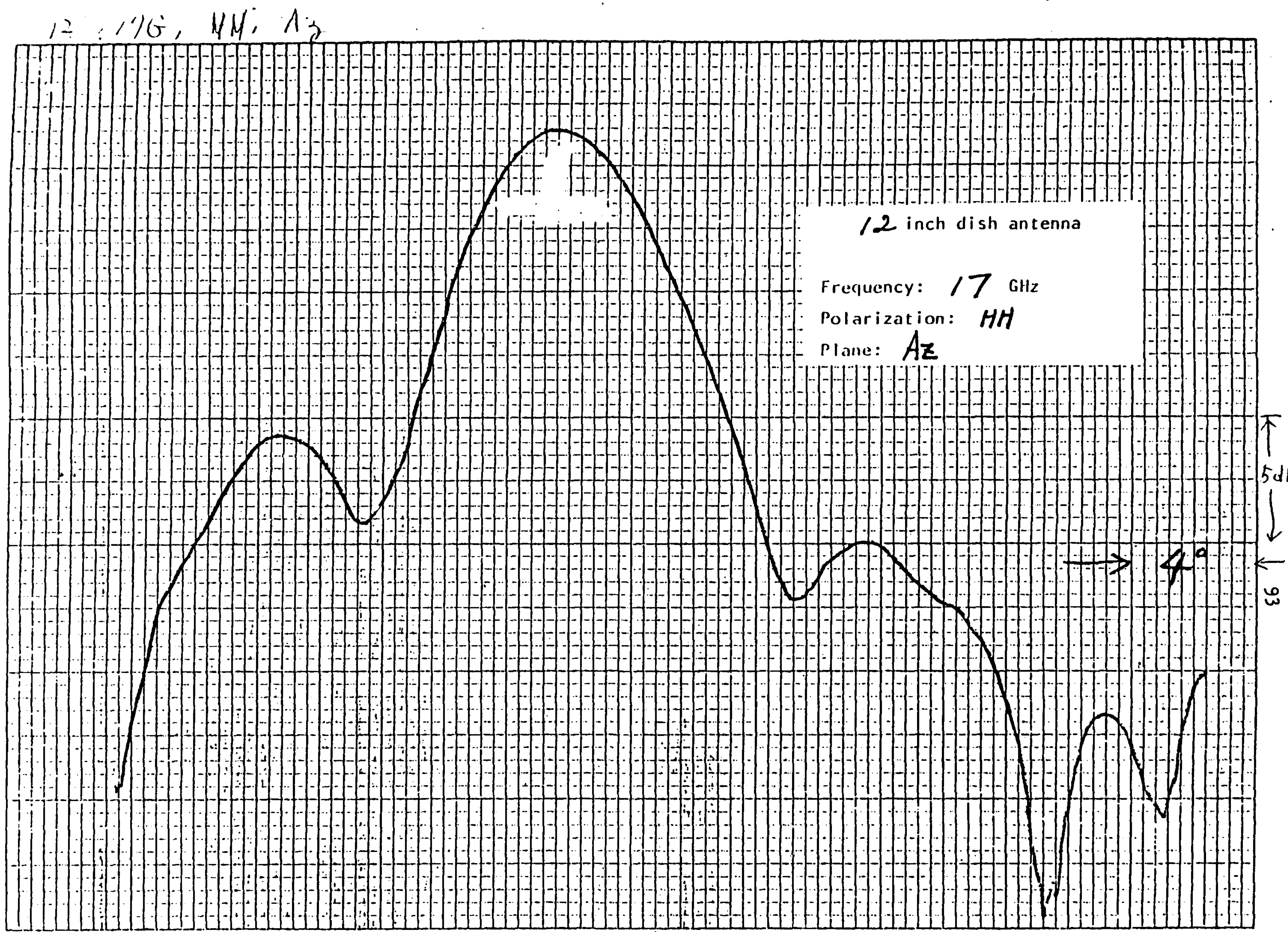


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

12" 1/16, VV, Az



12 inch dish antenna
Frequency: 17 GHz
Polarization: VV
Plane: Az.
5dB
4°
92


12 , 17G, HH, Az
12 inch dish antenna
Frequency: 17 GHz
Polarization: HH
Plane: Az
5dB
4°
93

APPENDIX D
FM BOARD CALIBRATION

Calibration procedure for triangle wave generator:

1. Disconnect the power cable to the RF box and then apply power.
2. Connect a scope between either T_1 or T_2 and ground pins on the board.
3. Set the frequency of the triangle wave to 600 Hz (using MAN FM) and adjust for symmetry using P2.
4. Set the frequency at 100 Hz and adjust for low frequency symmetry using P3.
5. Connect AC voltmeter between either T_1 or T_2 and ground pins and set the amplitude (sweep width) of the triangle wave as listed in table using P4 and P7 for Ku-X- and C-band, respectively.
6. Connect a DC voltmeter and adjust the DC offset and step size using potentiometers as follows:

	P5	step size for Ku-X-band
	P6	DC offset for Ku-X-band
	P8	step size for C-band
	P9	DC offset for C-band
Note:	P1	maximum frequency of oscillation
	P10	sets the maximum current into DAC

	Ku-X-Band	C-Band
Triangle wave amplitude	215 mV rms	354 mV rms
DC offset	0.6 V(DC)	4.0 V(DC)
FREQ step voltage	1.0 V(DC)	0.67 V(DC)

APPENDIX E
FAST RMS DETECTOR CALIBRATION

Do the following adjustments before mounting the TRMS module in the microprocessor cage. (See Figure B4.4b)

1. Connect DC voltmeter to Channel 1.
2. Apply ± 15 V from the HP power supply before turning on the instruments and wait for 5 minutes.
3. Connect the TRMS input to ground and adjust R_5 to get a minimum reading on the voltmeter, preferably zero.
4. Connect the DC voltmeter to Channel 2 and adjust R_{11} to get a zero volt indication.
5. Apply 10 mV, 1 kHz sine wave to the input and adjust R_6 so that Channel 1 output is 2130 mV ± 5 mV.
6. Increase the input to 50 mV and adjust the R_{12} so that Channel 2 output is 165 ± 3 mV.
7. After above calibration is done, install the module in the cage and connect the output connector to the A/D circuit board.

Do not connect the power supply ground to the signal ground. Connect the ground of signal cable to ground pin on the board marked as G.

APPENDIX F
RANGE TRACKER

F.1 System Concept

The range tracker was designed to interface with an FM-CW radar system, to allow the system to follow a rapidly moving target. As a result, the centroid of the return spectrum is kept at the same frequency, which facilitates data analysis, and the distance to the target can be determined in real time. The system block diagram is shown in Figure F.1. The frequency of the IF signal centroid is directly proportional to both the sweep rate and the time delay from the RF oscillator to the RF mixer, i.e., $f_{IF} \alpha f_{FM} \cdot T_{delay}$. If the sweep rate is constantly adjusted so that the IF remains constant, then $f_{FM} \alpha \frac{1}{T_{delay}}$. Thus, the distance to the target can be determined by measuring the frequency (sweep rate) and taking into account the delay associated with the antenna and feed lines. It is the range tracker's job to detect the frequency centroid of the IF signal, and keep it at the desired point by varying the sweep rate.

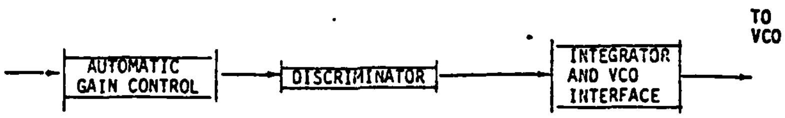


Figure F.1: System Block Diagram

F.2 Operation

The range tracker consists of three basic sections, shown in Figure F.1. The power return varies inversely with the square of the distance (for beam-limited conditions) and the target reflectivities also vary greatly, so that a very wide range of IF voltage can be anticipated. This would adversely affect the discriminator performance, so an automatic-gain-control circuit is provided. It has a 60 dB linear dynamic range, and it provides soft clipping for higher signal levels. The discriminator is a frequency-to-voltage converter, which outputs a positive DC voltage at low frequencies and a negative DC voltage at frequencies above the center frequency. The transfer characteristic for a sine wave input is shown in Figure F.2.

The discriminator voltage is fed to the integrator. When the IF frequency centroid is at its correct value, the discriminator output is zero, the integrator voltage does not change, and the VCO remains at the same frequency. If the IF centroid drifts too high, the discriminator produces a negative voltage, the integrator drifts to a more positive voltage, the VCO frequency is reduced, which lowers the IF centroid to the proper value. The reverse happens if the centroid

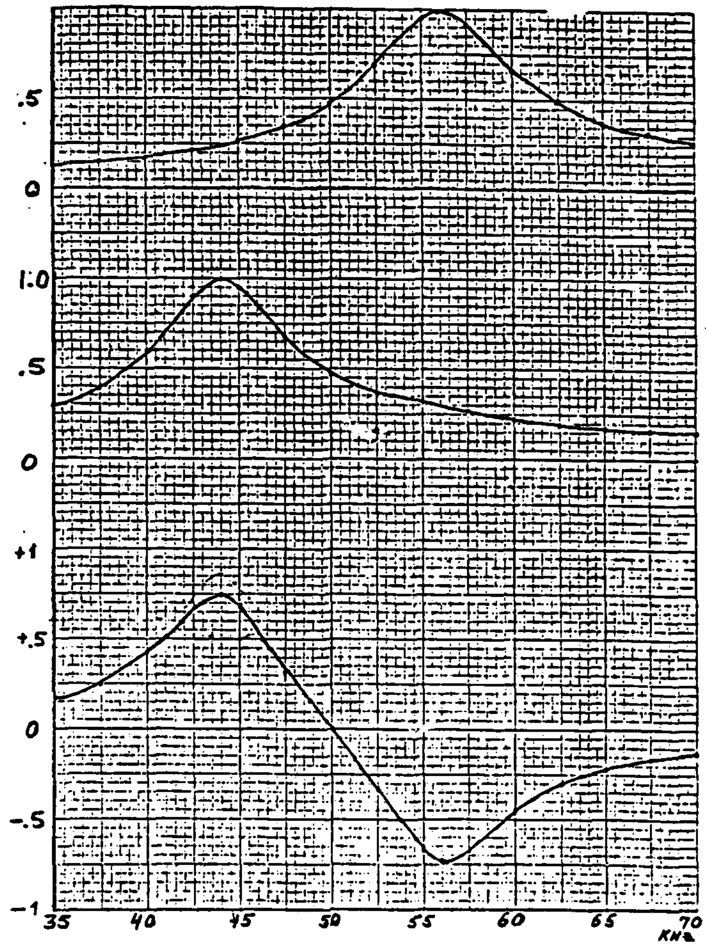


Figure F.2 Discriminator Characteristic

drifts too low. Circuitry is provided so that the integrator can be preset to any desired value by pushing a button. Thus, the distance to the target can be estimated, and then a preset is performed to bring the centroid into the capture range of the system. A linear mapping circuit is provided, which transforms the integrator's output voltage swing into the range required by the VCO.

F.3 Automatic Gain Control

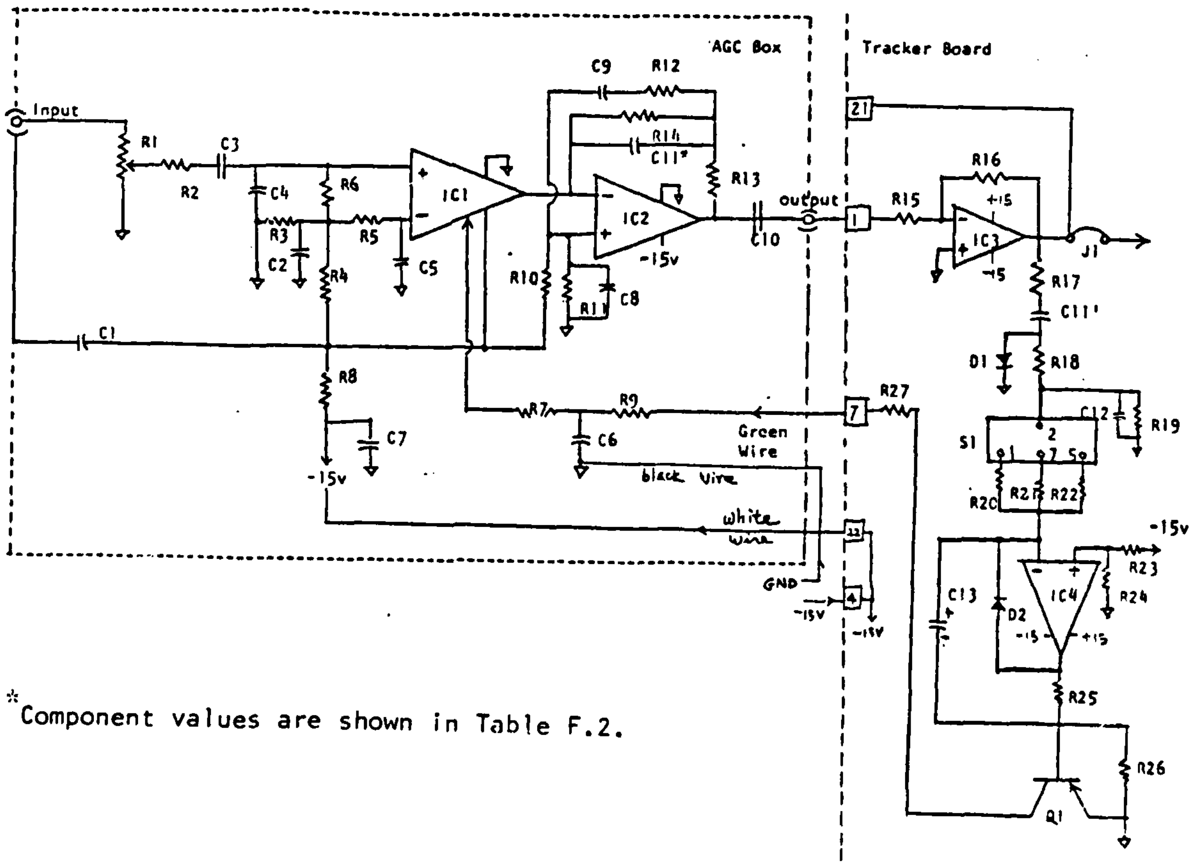
The AGC circuit uses a CA3080 OTA (operational transconductance amplifier) as the variable gain block. This chip has a differential input and a very high output impedance (i.e., current source). The transconductance $(\frac{\Delta I_O}{\Delta V_{IN}})$ is directly proportional to the current flowing into the control terminal, and is given by $g_m(\text{mho}) = 20\ I_{CONTROL(\mu A)}$. It is a two-quadrant multiplier, that is, the transconductance is always positive. The control input has a constant potential of one diode-drop above the V-supply. A 1000:1 gain ratio is easily obtained.

The transfer characteristic of the 3080 is simply that of a transistor differential amplifier, and reasonable linearity can be maintained up to a peak input of 50 mV. Because it deals with extremely small voltages, the gain control stage is enclosed in a metal box.

The full schematic is given in Figure F.3. R_1 attenuates the input signal to a level not to saturate the output. The current source output of IC 1 is converted to a low-impedance voltage source by IC 2. DC is removed by C10. IC 3 provides additional voltage gain. With a sine wave input, IC 3 output is 3.5 V_{pp}. Rectification of the output is provided by C11* and D1 and ripple is filtered by R18 and C12. A reference voltage is provided by R23 and R24, and voltage at inverted input terminal of IC 4 is -0.65 V at steady state. Switch S_1 changes the integrating time constant which determines the AGC range. Overall operation is as follows. If the input signal increases, the voltage at R19 becomes more negative and the integrator (IC 4) output then drifts more positive. The base voltage of Q1 decreases, causing lower current to IC 1.

F.4 Discriminator

The discriminator consists of two second-order bandpass filters and a summer, as shown in Figure F.4. The summer includes a one-pole ripple filter. The frequency response of the two filters, plus the overall frequency-to-DC response, is plotted in Figure F.2.



*Component values are shown in Table F.2.

Figure F.3: AGC Circuit

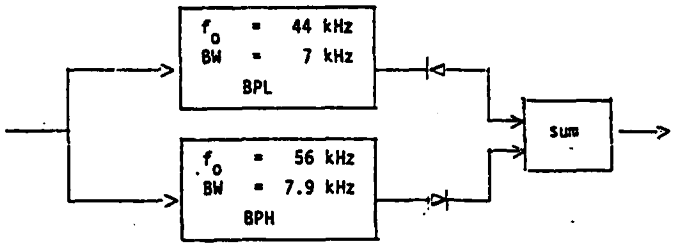


Figure F.4: Discriminator Block Diagram

To adjust the discriminator (see Figure F.5), connect a signal generator to the input (pin 21 when testing outside the system or IF input port at the back panel of the FM/IF module) and a DC voltmeter to the output. Locate the low-frequency peak, and adjust R33 until it is at 44 kHz. Then locate the high-frequency peak, and adjust R30 until it is at 56 kHz. Then adjust R40 for zero output at 50 kHz. The above three steps should be repeated until no further improvement can be obtained. If there is a need for external frequency-to-voltage converter, or a phase-detecting circuit, jumpers J1 and J2 can be removed and then the external circuit can be connected to edge connector pin 19 and pin 21.

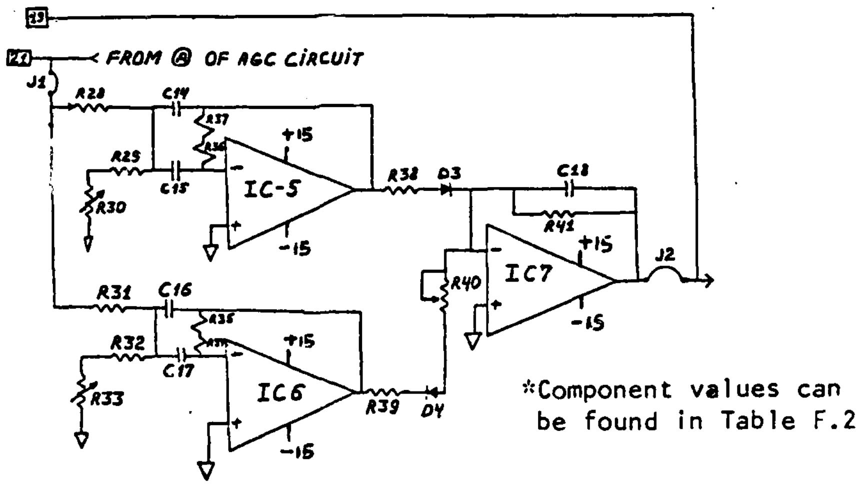


Figure F.5: Discriminator Circuit Diagram

F.5 Integrator, Preset and Mapping

The schematic is given in Figure F.6. The basic integrator is formed by IC9, Ci9 and the feedback network through the switches S2 and S3. Integrator preset is provided by IC10, which compares the voltage set by an external resistor with the integrator output. When reset push button on the front panel of the control box is depressed, the analog switch (IC12) is 'ON', and the error signal is fed back to the integrator input, and forces the output to the desired value. The output voltage range of the integrator (0 to +13 V) is mapped to the voltage

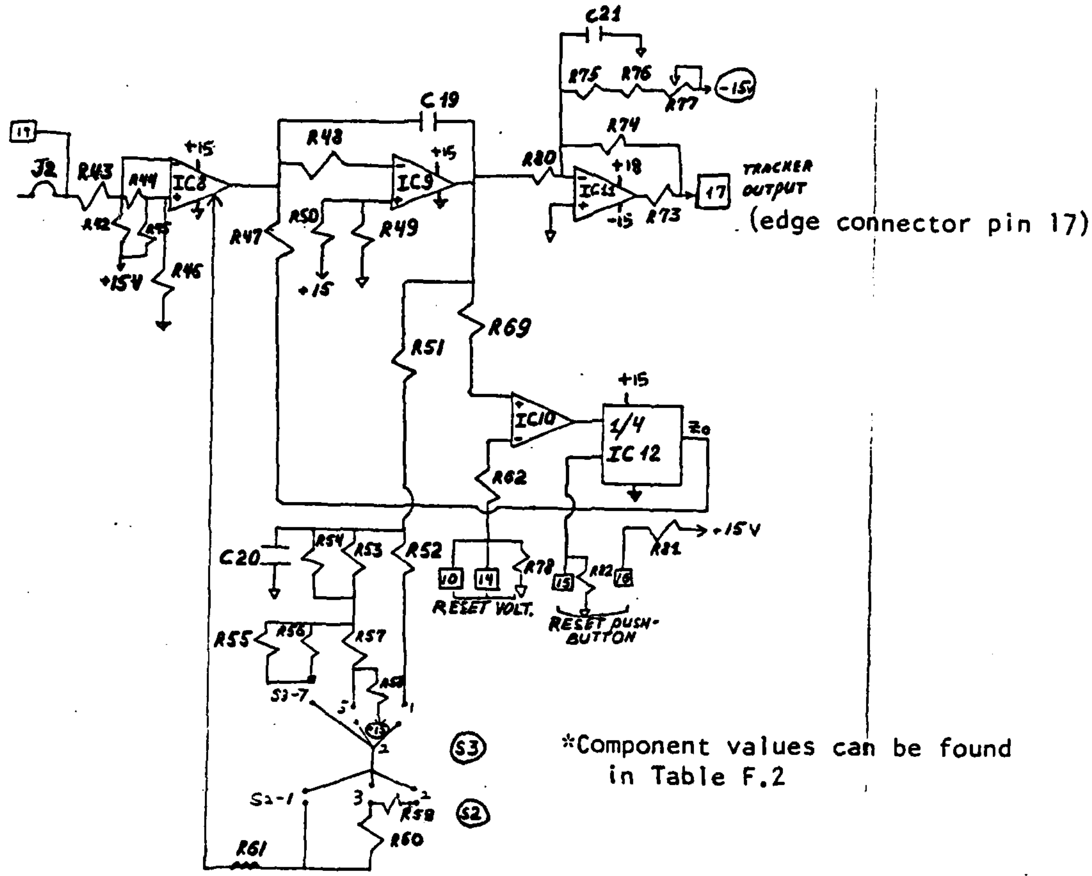


Figure F.6: Integrator and Mapping Circuit

required by the VCO (+5 to +15 V) by IC11. Supply voltage of +18 V is required by IC11 so that it can drive up to +15 volts. R77 is provided to set the low frequency limit (upper voltage limit). Feedback through switch S2, S3 compensates for signal-dependent time constant variation. S2 selects the time constants (1, 3.3, 10.1 sec) and S3 selects minimum to maximum frequency ratio (1/5, 1/10, 1/20). In the system, R77 should be adjusted until the lowest possible PRF forms the selected (by S3) ratio with the highest frequency. If no compensation is desired, the node of C20, R51, R52 can be connected to +15 V.

F.6 Test Procedures

The testing diagram is shown in Figure F.7.

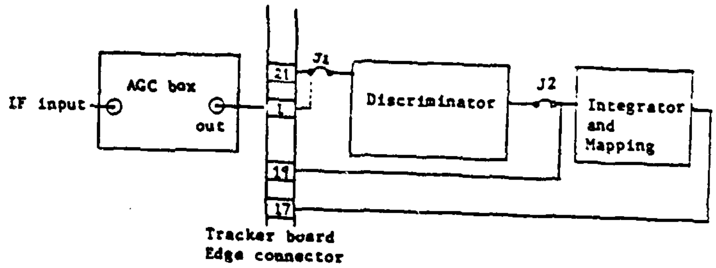


Figure F.7: Testing Diagram

F.6.1 AGC Section

This section, which is partly in a shielded box and partly in the range-tracker board can be tested by applying sine wave (50 kHz) to the IF input terminal of the AGC box and checking the output waveform at pin 21 of the tracker board. When changing the input signal level from 15 mV_{pp} to 5 V_{pp}, the output level should always be 3 V_{pp} at switch S1 upper position. Low level signals distort the output waveform, but it should contain strong input signal frequency component.

F.6.2 Discriminator Section

This section can be tested by applying the sine wave either to the IF input of the AGC box or to pin 19 of the range-tracker board when AGC box is disconnected. When changing the input signal frequency from 30 kHz to 70 kHz, the DC output voltage at pin 19 should have the same characteristics as Figure F.2 with the peak voltages around ± 3 V and 0V at 50 kHz.

F.6.3 Integrator and Mapping Section

This part is strictly a DC section and, therefore, can be tested by applying either DC voltage at pin 19 after removing the jumper wire J2 or sine wave to the IF input of the AGC box. Refer to Figure F.6. Voltage across R61 (current into IC8) should change when changing positions of the switches S2 and S3. And, the output voltage at pin 17 should have the characteristics shown in Figure F.8.

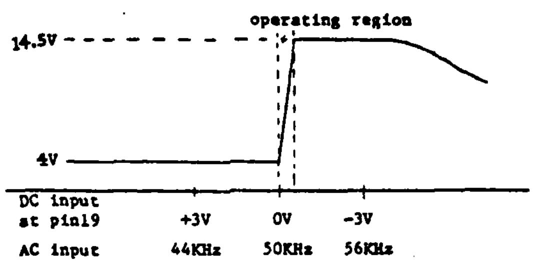
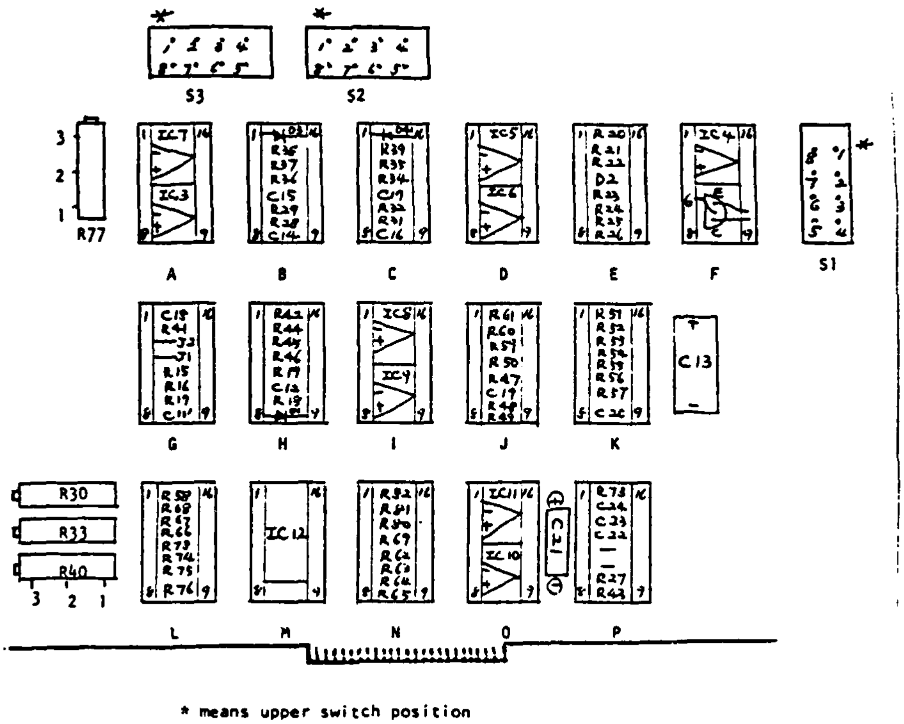


Figure F.8: Output Characteristic of the Range Tracker

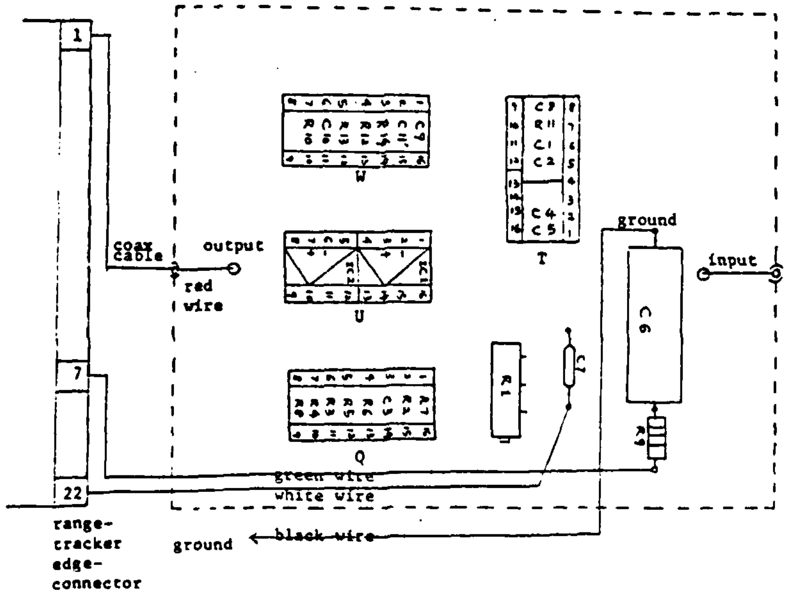
F.6.4 Precautions

The DC output voltage at pin 17 of this tracker board is a very sensitive function of power supply voltages. Therefore, in case of bad power supply fluctuations or in the case where the power supply voltages are adjusted higher than ±15.5 V and +18.5 V (as in the ship experiment where long power lines are required), the maximum DC output voltage may exceed +15 V which, in turn, may cause the

failure of the triangle board. Hence, whenever the power supply voltages exceed ±15.5 V or +18.5 V, it is suggested that the maximum output voltage of the tracker board is checked to have around 14.5 VDC at 56 kHz CW input. The voltages higher than 14.5 VDC should be reduced using R77.



Range Tracker Board Layout - Top View



AGC Box Layout - Top View

RANGE TRACKER BOARD WIRING LIST

TABLE F.1

A3-7-Gnd
A4-8-(-15v)
A11-15-(+15v)
A2-B16-(R40-1-2)-G1
A14-G16
A6-G5
A10-G11

B1-2
B3-4
B5-6-7-8
B9-14
B12-13-D2
B14-15-D14
(R30-2)-Gnd
(R33-2)-Gnd
B11-(R30-1)

C1-2
C3-4
C5-6-7-8
C14-15-D10
C12-13-D6
C9-14
C11-(R33-1)
C16-(R40-3)

D4-8-(-15v)
D3-7-Gnd
D11-15-(+15v)

E1-H10-11-12

E4-7-F14
E5-F4-(-15v)
E6-8-F11-Gnd
E9-10-F6-(C13-)
E11-12-F3
E13-14-15-16-F2-(C13+)

F15-(+15v)
F10-P10

G1-2
G14-15-16
G5-6
G7-8
G10-11-13-- 21
G12--------- 1
G9-H8
G3-P8-- 19
G4-C10-B10

H1-2-P9-12
H3-16-(+15v)
H4-5-6-9-Gnd
H7-8

H13-14-15-13

I4-8-Gnd
I6-J10
I10-K1-J11-N4
I11-15-J13-(+15v)
I14-J5

I13-J16

J1-2-(S2-1)
J3-(S2-2)
J4-8-17
J5-6-7
J9-K8-Gnd
J12-M2
J14-15-(S2-3)

K3-4-5-6-7
K9-13-14-15-16

K11-12-(S2-2)

L2-M14-- 13
L3-M6--- 12
L4-M5--- 11
L13-14-15-16
L5-Gnd
L6-7-O2
L8-(R77-1)
(R77-2-3)-(-15v)
L9-10-(C21-)
(C21+)-Gnd
L11-O14-- 17
L12-N5--- 14 -- 10

M3-11-12-N12-O6
M7-Gnd
M4-N9
M10-N10

M13-N11
M15-N16--- 15
M16-(+15v)

N1-Gnd
N2-(+15v)
N3-4
N7--- 9
N8--- 8
N14-O2
N15-- 16

O7-N13
O8-3-Gnd
O10-M1
O11-L13-(+15v)
O4-(-15v)

O15-(+18v)

P2-3-4--- 5 ←GND
P13------- 2 +18
P14------- 3 +15
P15--- 4 - 22 ←-15
P7-------- 7

TABLE F.2

TRACKER BOARD PARTS LIST

R15	6.8K
R16	150K
R17	3.3K
R18	33K
R19	33K
R20	100K*
R21	390K*
R22	1.5M*
R23	150K
R24	6.8K
R25	150K
R26	150K
R27	4.7K
R28	33K*
R29	390(33)
✓R30	500(69)
R31	33K*
R32	680(100)
✓R33	500(78)
R34	68K*(82K)
R35	68K*(330K)
R36	120K*(150K)
R37	---(220K)
R38	15K
R39	12K(15K)
✓R40	10K(9.47K)
R41	120K
R42	12K
R43	12K
R44	100
R45	12K

R46	12K
R47	4.7K
R48	12K
R49	12K
R50	12K
R51	12K*
R52	12K*
R53	12K*
R54	12K*
R55	15K*
R56	15K*
R57	12K*
R58	120K*
R59	270K*
R60	82K*
R61	12K*
R62	1.5M
R63	12K
R64	12K
R65	12K
R66	12K
R67	12K
R68	12K
R69	12K
✓R70	5K
✓R71	5K
✓R72	5K
R73	680(removed)
R74	33K*(27K)
R75	18K(12K)
R76	12K

✓R77	10K
R78	12K
R79	---
R80	47K(39K)
R81	12K
R82	120K
C11	.1*
C12	.1
C13	1.0
C14	330p*
C15	330p*
C16	330p*
C17	330p*
C18	.01
C19	.22
C20	.01
C21	10
C22	.1
C23	.1(removed)
C24	.1
Q1	2N3906
D1-4	Ge Diodes
IC3-7	CA3140
IC8	CA3080
IC9-11	CA3140
IC12	CD4066 (MC14066)

AGC BOX

✓R1	10K
R2	6.8K
R3	12K
R4	12K
R5	1.0K*
R6	1.0K*
R7	1.5K
R8	1.0K
R9	1.5K
R10	12K
R11	12K
R12	4.7K
R13	47K
R14	47K
C1	.1
C2	.01
C3	.01
C4	330p
C5	.01
C6-9	.1
C10	.01
C11*	22p
IC1	CA3080
IC2	CA3140

AGC BOX WIRING LIST

Input-(R1-3)
Green-(R9)
(-15v)-Black-(c7)

T1-2-3-4-5-6-7-8-(C6)-Gnd
T9-10-U7-W1
T11-Q7-8-U4-W10
T12-Q3
T13-14-Q6-U15-U11-Gnd
T15-U3-Q3-4
T16-U2-Q5

U13-Q1
U14-U6

W2-3-4-5
W6-Output
W7-U7
W10-U8
W11-12-U10
W13-16
W14-15-U6

Q9-(-15v)
Q10-11-12-13
Q14-15

(R1-2)-Q2
(R1-1)-Q1
(R9)-(C6)-Q16

✓ means variable resistors
* means 5% tolerance recommended
() indicates new discriminator design values

APPENDIX G
ELECTRICAL LOAD ANALYSIS

I. Aircraft Source Voltage Required = +28 VDC
Maximum Current Required = 30.5 A

II. Electronics Package Current Required = 8.5 A continuous
Actuator Current Req. under Stall = 22.0 A
Actuator Current Req. under Load = 10.0 A

III. Detailed Analysis:
Power Supplies:

Voltage	Current Supplied-A-	Max Current Capability-A-
+18	2.77	5.0
+15	.90	2.2
+12	1.40 - 2.20	2.2
+ 5	5.77	9.0
-18	.73	2.3
-15	.42	2.2
-12	.25	2.2
- 5	.10	2.2

Devices:

	Instrument/Device	Supply AC(Volts)	Supply DC(Volts)	Current load(mA/device)	Power	# devices
1	IF amplifier	115	---		10	1
2	T.R.M.S. meter	115	---	---	4	1
3	Frequency counter	115	---	---	7	1
4	Altimeter	---	28	600	--	1
5	HP switches	---	28	120	--	2
6	Transco switches	---	28	120	--	5
7	Fans	---	28	220	--	2
8	X -KU band oscillator	---	28	180	--	1
		---	18	500	--	1
		---	-18	100		
9	Microprocessor	---	12	400	--	1
		---	-12	250	--	
		---	5	5000	--	
		---	- 5	10		
10	A/D convertor	---	15	150	--	1
	and associated circuits	---	-15	150	--	
11	Recorder	---	12	1000(average)		1
		---	5	700(average)		
12	C-band oscillator	---	+15	650	--	1
		---	-15	100	--	
		---	28	50		
13	FM generator	---	15	50	--	1
	and range tracker	---	-15	50	--	
		---	18	20	--	
		---	5	10	--	
14	Pin diode switch	---	-15	65	--	1
		---	5	50	--	1
15	Actuator control	---	28	10,000(average)		1
				22,000(peak)	--	

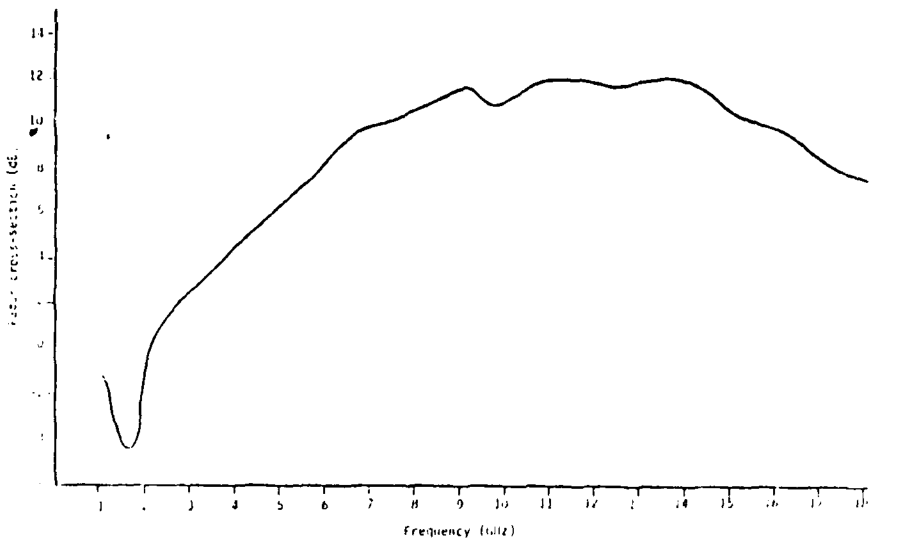
APPENDIX H
HELOSCAT SYSTEM WEIGHTS

Data Acquisition Module	= 30	13.6
Power and IF Processing Module	= 67.5	30.6
RF Module	= 8.5	3.9
HELOSCAT Structure	= 49.0	22.3
24" Dish Antenna	= 14.0	6.4
18" Dish Antenna	= 9.0	4.1
Radar Altimeter and Mount	= 8.0	3.6
TOTAL WEIGHT	= 181.0 lbs.	82.3 kg

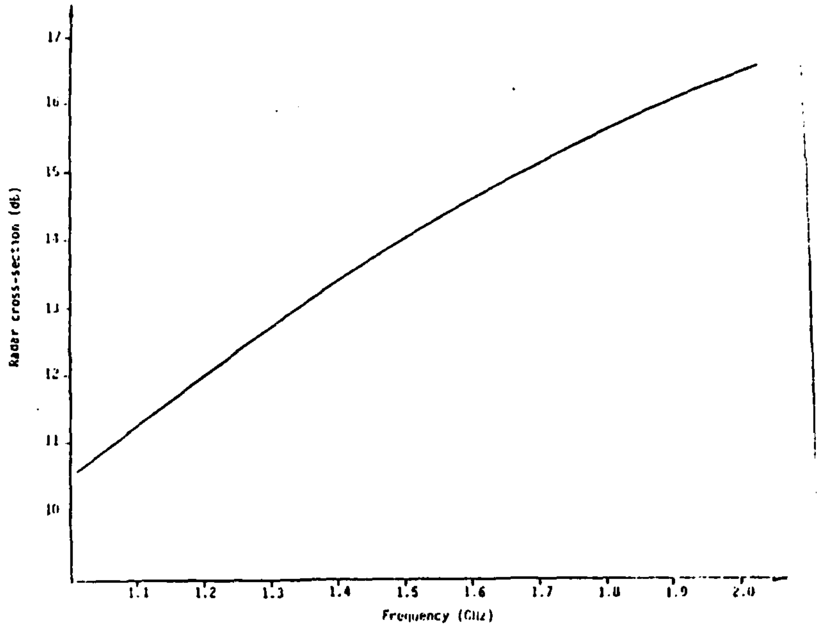
APPENDIX I
STANDARD RADAR TARGETS

Luneberg Lens Cross-Section (#328)

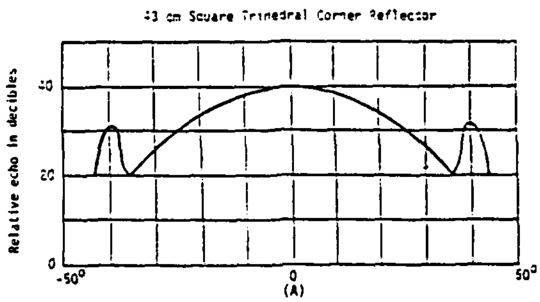
Frequency (GHz)	Cross-Section (dB rel. to 1 m^2)
1.5	- 4.5
4.4	5.3
4.8	6.1
5.2	6.7
5.6	7.4
6.0	8.4
6.4	8.8
6.8	9.7
7.2	9.8
7.6	10.2
8.6	11.2
9.6	10.8
10.6	11.6
11.6	11.8
12.6	11.6
13.6	11.9
14.6	11.0
15.6	9.9
16.6	8.9

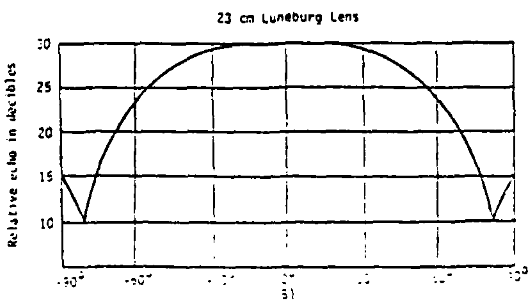


Frequency response of Luneberg lens reflector



Theoretical 1-2 GHz radar cross-section response of 43 cm square trihedral corner reflector





Angular response of standard targets

APPENDIX J

HELOSCAT System Footprint Sizes and Independent Samples

ANTENNA HEIGHT= 15.2 METERS(50. FEET)

POLARIZATION= VV (18 INCH DISH)

INCIDENCE ANGLE= 10 DEGREES

FREQUENCY	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	4.38	3.85	13.27	4
4.4 GHZ	2.26	2.01	3.56	2
4.8 GHZ	2.07	1.86	3.02	2
5.2 GHZ	1.92	1.70	2.57	2
5.6 GHZ	1.79	1.61	2.27	2
6.0 GHZ	1.70	1.46	1.95	1
6.4 GHZ	1.42	1.40	1.56	1
6.8 GHZ	1.36	1.31	1.40	1
7.2 GHZ	1.33	1.22	1.27	1
7.6 GHZ	1.30	1.15	1.18	1
8.6 GHZ	1.03	1.00	0.85	1
9.6 GHZ	1.02	0.91	0.73	1
10.6 GHZ	0.96	0.82	0.62	1
11.6 GHZ	0.83	0.76	0.50	1
12.6 GHZ	0.80	0.67	0.42	1
13.6 GHZ	0.80	0.64	0.40	1
14.6 GHZ	0.77	0.64	0.39	1
15.6 GHZ	0.74	0.53	0.34	1
16.6 GHZ	0.65	0.52	0.26	1

INCIDENCE ANGLE= 20 DEGREES

FREQUENCY	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	4.93	4.04	15.71	8
4.4 GHZ	2.43	2.11	4.11	4
4.8 GHZ	2.23	1.95	3.49	4
5.2 GHZ	2.11	1.79	2.96	4
5.6 GHZ	1.97	1.69	2.62	3
6.0 GHZ	1.87	1.53	2.25	3
6.4 GHZ	1.56	1.47	1.80	3
6.8 GHZ	1.49	1.37	1.61	3
7.2 GHZ	1.46	1.28	1.46	2
7.6 GHZ	1.43	1.21	1.36	2
8.6 GHZ	1.19	1.05	0.98	2
9.6 GHZ	1.12	0.96	0.84	2
10.6 GHZ	1.05	0.86	0.71	2
11.6 GHZ	0.92	0.80	0.57	2
12.6 GHZ	0.83	0.70	0.49	2
13.6 GHZ	0.88	0.67	0.46	2
14.6 GHZ	0.85	0.67	0.45	1
15.6 GHZ	0.81	0.61	0.39	1
16.6 GHZ	0.71	0.54	0.30	1

INCIDENCE ANGLE= 30 DEGREES

FREQUENCY	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	5.70	4.39	19.69	14
4.4 GHZ	2.92	2.29	5.25	7
4.8 GHZ	2.63	2.11	4.45	7
5.2 GHZ	2.43	1.94	3.79	6
5.6 GHZ	2.32	1.84	3.35	6
6.0 GHZ	2.20	1.66	2.87	6
6.4 GHZ	1.84	1.59	2.30	5
6.8 GHZ	1.75	1.49	2.05	4
7.2 GHZ	1.72	1.73	1.87	4
7.6 GHZ	1.68	1.71	1.73	4
8.6 GHZ	1.40	1.14	1.25	3
9.6 GHZ	1.32	1.04	1.07	3
10.6 GHZ	1.24	0.93	0.91	3
11.6 GHZ	1.03	0.86	0.73	3
12.6 GHZ	1.04	0.76	0.62	3
13.6 GHZ	1.04	0.73	0.59	3
14.6 GHZ	1.00	0.73	0.57	2
15.6 GHZ	0.96	0.66	0.49	2
16.6 GHZ	0.84	0.59	0.39	2

INCIDENCE ANGLE= 40 DEGREES

FREQUENCY	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	7.34	4.99	28.75	24
4.4 GHZ	3.75	2.59	7.61	12
4.8 GHZ	3.43	2.39	6.45	11
5.2 GHZ	3.18	2.19	5.47	10
5.6 GHZ	2.97	2.08	4.84	10
6.0 GHZ	2.82	1.89	4.16	9
6.4 GHZ	2.55	1.80	3.33	8
6.8 GHZ	2.25	1.68	2.97	7
7.2 GHZ	2.22	1.57	2.70	7
7.6 GHZ	2.15	1.49	2.51	7
8.6 GHZ	1.79	1.29	1.31	6
9.6 GHZ	1.69	1.17	1.55	5
10.6 GHZ	1.53	1.05	1.31	5
11.6 GHZ	1.38	0.98	1.06	4
12.6 GHZ	1.33	0.86	0.70	4
13.6 GHZ	1.33	0.72	0.85	4
14.6 GHZ	1.23	0.82	0.82	4
15.6 GHZ	1.25	0.74	0.72	4
16.6 GHZ	1.07	0.66	0.56	5

ANTENNA HEIGHT= 15.2 METERS(50. FEET)

POLARIZATION= HH (24 INCH DISH)

INCIDENCE ANGLE= 10 DEGREES

FREQ.(GHZ)	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	2.51	2.65	5.22	2
4.4 GHZ	1.53	1.64	2.03	1
4.8 GHZ	1.43	1.55	1.81	1
5.2 GHZ	1.39	1.43	1.56	1
5.6 GHZ	1.30	1.37	1.40	1
6.0 GHZ	1.20	1.28	1.21	1
6.4 GHZ	1.14	1.19	1.07	1
6.8 GHZ	1.03	1.13	0.96	1
7.2 GHZ	1.02	1.06	0.85	1
7.6 GHZ	0.96	1.00	0.75	1
8.6 GHZ	0.85	0.89	0.59	1
9.6 GHZ	0.74	0.79	0.46	1
10.6 GHZ	0.69	0.73	0.39	1
11.6 GHZ	0.62	0.67	0.32	1
12.6 GHZ	0.59	0.64	0.29	1
13.6 GHZ	0.52	0.64	0.26	0
14.6 GHZ	0.49	0.61	0.24	0
15.6 GHZ	0.46	0.61	0.22	0
16.6 GHZ	0.43	0.58	0.20	0

INCIDENCE ANGLE= 20 DEGREES

FREQ.(GHZ)	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	2.76	2.79	6.02	5
4.4 GHZ	1.73	1.72	2.34	3
4.8 GHZ	1.63	1.63	2.08	3
5.2 GHZ	1.53	1.50	1.80	3
5.6 GHZ	1.43	1.44	1.61	2
6.0 GHZ	1.32	1.34	1.39	2
6.4 GHZ	1.26	1.24	1.23	2
6.8 GHZ	1.19	1.18	1.10	2
7.2 GHZ	1.12	1.12	0.93	2
7.6 GHZ	1.05	1.05	0.87	2
8.6 GHZ	0.92	0.92	0.66	2
9.6 GHZ	0.81	0.83	0.53	1
10.6 GHZ	0.75	0.76	0.45	1
11.6 GHZ	0.63	0.70	0.37	1
12.6 GHZ	0.64	0.67	0.34	1
13.6 GHZ	0.53	0.67	0.30	1
14.6 GHZ	0.54	0.64	0.27	1
15.6 GHZ	0.51	0.64	0.25	1
16.6 GHZ	0.47	0.61	0.23	1

INCIDENCE ANGLE= 30 DEGREES

FREQ.(GHZ)	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	3.25	3.02	7.70	8
4.4 GHZ	2.04	1.37	3.00	5
4.8 GHZ	1.92	1.77	2.66	5
5.2 GHZ	1.80	1.63	2.30	5
5.6 GHZ	1.63	1.56	2.05	4
6.0 GHZ	1.56	1.45	1.79	4
6.4 GHZ	1.49	1.35	1.57	4
6.8 GHZ	1.40	1.29	1.41	3
7.2 GHZ	1.32	1.21	1.25	3
7.6 GHZ	1.24	1.14	1.11	3
8.6 GHZ	1.03	1.00	0.85	3
9.6 GHZ	0.96	0.90	0.69	2
10.6 GHZ	0.88	0.83	0.57	2
11.6 GHZ	0.80	0.76	0.48	2
12.6 GHZ	0.76	0.73	0.43	2
13.6 GHZ	0.63	0.73	0.39	2
14.6 GHZ	0.64	0.69	0.35	2
15.6 GHZ	0.60	0.69	0.33	1
16.6 GHZ	0.56	0.66	0.29	1

INCIDENCE ANGLE= 40 DEGREES

FREQ.(GHZ)	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	4.16	3.42	11.17	13
4.4 GHZ	2.61	2.11	4.33	3
4.8 GHZ	2.46	2.00	3.85	3
5.2 GHZ	2.30	1.84	3.32	7
5.6 GHZ	2.15	1.76	2.97	7
6.0 GHZ	1.99	1.64	2.57	6
6.4 GHZ	1.89	1.53	2.27	6
6.8 GHZ	1.79	1.45	2.03	6
7.2 GHZ	1.69	1.37	1.81	5
7.6 GHZ	1.59	1.29	1.61	5
8.6 GHZ	1.53	1.13	1.23	4
9.6 GHZ	1.23	1.02	0.98	4
10.6 GHZ	1.12	0.94	0.83	4
11.6 GHZ	1.02	0.86	0.69	3
12.6 GHZ	0.97	0.82	0.63	3
13.6 GHZ	0.87	0.82	0.56	3
14.6 GHZ	0.82	0.79	0.50	3
15.6 GHZ	0.77	0.79	0.47	2
16.6 GHZ	0.71	0.71	0.42	2

INCIDENCE ANGLE= 50 DEGREES

FREQUENCY	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	6.90	5.98	44.50	34
4.4 GHZ	5.34	3.09	12.96	21
4.8 GHZ	4.89	2.85	10.97	19
5.2 GHZ	4.52	2.62	9.30	17
5.6 GHZ	4.23	2.45	8.23	16
6.0 GHZ	4.01	2.24	7.06	15
6.4 GHZ	3.75	2.15	5.64	13
6.8 GHZ	3.20	2.01	5.09	12
7.2 GHZ	3.17	1.87	4.59	12
7.6 GHZ	3.05	1.77	4.25	12
8.6 GHZ	2.54	1.54	3.07	10
9.6 GHZ	2.40	1.40	2.67	9
10.6 GHZ	2.25	1.26	2.23	9
11.6 GHZ	1.96	1.17	1.79	8
12.6 GHZ	1.89	1.03	1.52	7
13.6 GHZ	1.89	0.93	1.45	7
14.6 GHZ	1.81	0.98	1.39	7
15.6 GHZ	1.74	0.89	1.21	7
16.6 GHZ	1.52	0.79	0.95	6

INCIDENCE ANGLE= 50 DEGREES

FREQ.(GHZ)	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	5.31	4.08	19.03	23
4.4 GHZ	3.71	2.52	7.36	14
4.8 GHZ	3.49	2.38	6.53	13
5.2 GHZ	3.27	2.19	5.64	13
5.6 GHZ	3.05	2.10	5.04	12
6.0 GHZ	2.83	1.96	4.36	11
6.4 GHZ	2.67	1.82	3.34	10
6.8 GHZ	2.54	1.73	3.45	10
7.2 GHZ	2.40	1.63	3.07	9
7.6 GHZ	2.25	1.54	2.72	9
8.6 GHZ	1.96	1.35	2.08	8
9.6 GHZ	1.74	1.21	1.66	7
10.6 GHZ	1.60	1.12	1.40	6
11.6 GHZ	1.45	1.03	1.17	6
12.6 GHZ	1.38	0.98	1.06	5
13.6 GHZ	1.23	0.98	0.95	5
14.6 GHZ	1.16	0.93	0.85	4
15.6 GHZ	1.09	0.93	0.80	4
16.6 GHZ	1.01	0.89	0.71	4

INCIDENCE ANGLE= 60 DEGREES

FREQUENCY	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	10.47	7.32	75.12	45
4.4 GHZ	8.90	3.99	27.88	39
4.8 GHZ	8.14	3.68	23.55	35
5.2 GHZ	7.52	3.38	19.94	33
5.6 GHZ	7.02	3.19	17.61	30
6.0 GHZ	6.65	2.89	15.10	29
6.4 GHZ	5.55	2.77	12.05	24
6.8 GHZ	5.30	2.58	10.76	23
7.2 GHZ	5.13	2.40	9.73	22
7.6 GHZ	5.06	2.28	9.07	22
8.6 GHZ	4.21	1.98	6.55	18
9.6 GHZ	3.97	1.80	5.61	17
10.6 GHZ	3.72	1.62	4.74	16
11.6 GHZ	3.24	1.50	3.82	14
12.6 GHZ	3.12	1.32	3.23	14
13.6 GHZ	3.12	1.26	3.09	14
14.6 GHZ	3.00	1.26	2.97	13
15.6 GHZ	2.99	1.14	2.53	12
16.6 GHZ	2.52	1.02	2.02	11

INCIDENCE ANGLE= 60 DEGREES

FREQ.(GHZ)	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	9.37	5.27	40.16	41
4.4 GHZ	6.16	3.25	15.72	27
4.8 GHZ	5.73	3.07	13.95	25
5.2 GHZ	5.43	2.83	12.04	24
5.6 GHZ	5.06	2.70	10.74	22
6.0 GHZ	4.69	2.52	9.30	20
6.4 GHZ	4.45	2.31	8.19	19
6.8 GHZ	4.21	2.22	7.34	18
7.2 GHZ	3.87	2.10	6.54	17
7.6 GHZ	3.72	1.98	5.79	16
8.6 GHZ	3.24	1.74	4.43	14
9.6 GHZ	2.88	1.56	3.53	12
10.6 GHZ	2.64	1.44	2.93	11
11.6 GHZ	2.40	1.32	2.48	10
12.6 GHZ	2.23	1.26	2.25	10
13.6 GHZ	2.04	1.26	2.01	9
14.6 GHZ	1.92	1.20	1.81	8
15.6 GHZ	1.80	1.20	1.69	8
16.6 GHZ	1.68	1.14	1.50	7

INCIDENCE ANGLE= 70 DEGREES

FREQUENCY	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	13.65	12.01	146.70	64
4.4 GHZ	13.65	5.90	70.82	64
4.8 GHZ	13.65	5.44	63.79	64
5.2 GHZ	13.56	4.98	56.65	64
5.6 GHZ	13.18	4.70	51.72	62
6.0 GHZ	12.89	4.25	45.42	61
6.4 GHZ	11.97	4.06	38.18	56
6.8 GHZ	11.43	3.79	34.07	54
7.2 GHZ	11.17	3.53	30.94	53
7.6 GHZ	10.90	3.35	28.68	51
8.6 GHZ	9.04	2.90	20.62	43
9.6 GHZ	8.52	2.64	17.65	40
10.6 GHZ	7.99	2.37	14.90	38
11.6 GHZ	6.95	2.20	11.93	33
12.6 GHZ	6.69	1.93	10.15	31
13.6 GHZ	6.69	1.84	9.69	31
14.6 GHZ	6.43	1.84	9.31	30
15.6 GHZ	6.17	1.67	8.08	29
16.6 GHZ	5.39	1.49	6.32	25

INCIDENCE ANGLE= 70 DEGREES

FREQ.(GHZ)	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	13.65	7.83	95.55	64
4.4 GHZ	12.50	4.78	48.70	59
4.8 GHZ	12.20	4.51	43.99	57
5.2 GHZ	11.70	4.15	38.13	55
5.6 GHZ	10.90	3.97	33.97	51
6.0 GHZ	10.10	3.70	29.35	47
6.4 GHZ	9.57	3.43	25.81	45
6.8 GHZ	9.04	3.26	23.13	43
7.2 GHZ	8.52	3.09	20.59	40
7.6 GHZ	7.99	[illegible]	18.21	38
8.6 GHZ	6.95	[illegible]	13.90	33
9.6 GHZ	6.17	2.28	11.06	29
10.6 GHZ	5.65	2.11	9.35	27
11.6 GHZ	5.14	1.93	7.73	24
12.6 GHZ	4.88	1.84	7.05	23
13.6 GHZ	4.36	1.84	6.31	20
14.6 GHZ	4.10	1.75	5.65	19
15.6 GHZ	3.85	1.75	5.29	18
16.6 GHZ	3.59	1.66	4.69	17

INCIDENCE ANGLE= 80 DEGREES

FREQUENCY	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	24.83	35.85	536.48	122
4.4 GHZ	24.83	12.49	276.31	122
4.8 GHZ	24.83	11.36	254.35	122
5.2 GHZ	24.83	10.31	232.04	122
5.6 GHZ	24.83	9.67	219.52	122
6.0 GHZ	24.83	8.71	198.04	122
6.4 GHZ	24.83	8.21	186.55	122
6.8 GHZ	24.83	7.65	175.42	122
7.2 GHZ	24.83	7.11	166.32	122
7.6 GHZ	24.83	6.74	152.27	122
8.6 GHZ	24.83	5.86	127.77	122
9.6 GHZ	24.83	5.27	114.33	122
10.6 GHZ	24.83	4.73	[illegible]	122
11.6 GHZ	24.04	[illegible]	87.50	118
12.6 GHZ	[illegible]	3.84	79.15	117
13.6 GHZ	23.66	3.66	71.72	117
14.6 GHZ	23.23	3.66	[illegible]	115
15.6 GHZ	[illegible]	[illegible]	[illegible]	[illegible]
16.6 GHZ	[illegible]	[illegible]	[illegible]	[illegible]

INCIDENCE ANGLE= 80 DEGREES

FREQ.(GHZ)	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	24.83	16.87	356.32	122
4.4 GHZ	24.83	9.72	221.36	122
4.8 GHZ	24.83	9.14	207.81	122
5.2 GHZ	24.83	8.38	190.10	122
5.6 GHZ	24.83	7.99	[illegible]	122
6.0 GHZ	24.83	7.43	166.29	122
6.4 GHZ	24.83	6.88	152.87	122
6.8 GHZ	24.83	6.51	[illegible]	122
7.2 GHZ	24.83	6.14	[illegible]	122
7.6 GHZ	24.83	5.78	[illegible]	122
8.6 GHZ	24.04	[illegible]	[illegible]	113
9.6 GHZ	22.90	[illegible]	[illegible]	115
10.6 GHZ	22.12	[illegible]	72.66	109
11.6 GHZ	20.12	3.82	60.32	99
12.6 GHZ	[illegible]	3.64	54.00	[illegible]
13.6 GHZ	17.01	3.64	[illegible]	[illegible]
14.6 GHZ	[illegible]	3.46	[illegible]	[illegible]
15.6 GHZ	[illegible]	3.46	40.71	[illegible]
16.6 GHZ	[illegible]	[illegible]	36.11	[illegible]

ANTENNA HEIGHT= 30.4 METERS(100. FEET)

POLARIZATION= VV (13 INCH DISH)

INCIDENCE ANGLE= 10 DEGREES

FREQUENCY	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	3.77	7.70	53.06	9
4.4 GHZ	4.52	4.02	14.26	4
4.8 GHZ	4.14	3.71	12.09	4
5.2 GHZ	3.83	3.41	10.27	3
5.6 GHZ	3.53	3.23	9.09	3
6.0 GHZ	3.40	2.92	7.80	3
6.4 GHZ	2.34	2.80	6.25	2
6.8 GHZ	2.72	2.62	5.59	2
7.2 GHZ	2.66	2.43	5.08	2
7.6 GHZ	2.60	2.31	4.71	2
8.6 GHZ	2.16	2.01	3.41	2
9.6 GHZ	2.04	1.82	2.92	2
10.6 GHZ	1.91	1.64	2.47	2
11.6 GHZ	1.67	1.52	1.99	1
12.6 GHZ	1.61	1.34	1.69	1
13.6 GHZ	1.61	1.28	1.61	1
14.6 GHZ	1.54	1.29	1.55	1
15.6 GHZ	1.43	1.16	1.35	1
16.6 GHZ	1.30	1.03	1.05	1

INCIDENCE ANGLE= 20 DEGREES

FREQUENCY	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	9.65	8.08	61.26	17
4.4 GHZ	4.96	4.21	16.43	9
4.8 GHZ	4.55	3.89	13.92	8
5.2 GHZ	4.21	3.57	11.82	7
5.6 GHZ	3.34	3.38	10.46	7
6.0 GHZ	3.74	3.06	8.93	6
6.4 GHZ	3.12	2.93	7.20	5
6.8 GHZ	2.99	2.74	6.43	5
7.2 GHZ	2.92	2.55	5.85	5
7.6 GHZ	2.35	2.42	5.43	5
8.6 GHZ	2.58	2.10	3.93	4
9.6 GHZ	2.24	1.91	3.36	4
10.6 GHZ	2.10	1.72	2.84	4
11.6 GHZ	1.93	1.53	2.29	3
12.6 GHZ	1.76	1.40	1.94	3
13.6 GHZ	1.76	1.34	1.85	3
14.6 GHZ	1.70	1.34	1.78	3
15.6 GHZ	1.63	1.21	1.55	3
16.6 GHZ	1.42	1.08	1.21	2

INCIDENCE ANGLE= 30 DEGREES

FREQUENCY	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	11.41	8.79	78.72	29
4.4 GHZ	5.85	4.57	21.02	15
4.8 GHZ	5.37	4.23	17.81	13
5.2 GHZ	4.96	3.88	15.12	12
5.6 GHZ	4.64	3.67	13.38	12
6.0 GHZ	4.40	3.32	11.49	11
6.4 GHZ	3.68	3.18	9.20	9
6.8 GHZ	3.52	2.98	8.22	9
7.2 GHZ	3.44	2.77	7.47	9
7.6 GHZ	3.36	2.63	6.94	8
8.6 GHZ	2.80	2.28	5.02	7
9.6 GHZ	2.64	2.08	4.30	7
10.6 GHZ	2.48	1.87	3.63	6
11.6 GHZ	2.16	1.73	2.93	5
12.6 GHZ	2.08	1.52	2.48	5
13.6 GHZ	2.03	1.45	2.37	5
14.6 GHZ	2.00	1.45	2.28	5
15.6 GHZ	1.92	1.31	1.93	5
16.6 GHZ	1.69	1.19	1.55	4

INCIDENCE ANGLE= 40 DEGREES

FREQUENCY	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	14.69	9.97	115.00	48
4.4 GHZ	7.49	5.19	30.45	24
4.8 GHZ	6.37	4.73	25.80	22
5.2 GHZ	6.35	4.39	21.89	20
5.6 GHZ	5.94	4.15	19.37	19
6.0 GHZ	5.63	3.76	16.62	13
6.4 GHZ	4.70	3.60	13.31	15
6.8 GHZ	4.50	3.37	11.89	14
7.2 GHZ	4.40	3.13	10.81	14
7.6 GHZ	4.29	2.97	10.03	14
8.6 GHZ	3.58	2.58	7.25	12
9.6 GHZ	3.37	2.35	6.21	11
10.6 GHZ	3.17	2.11	5.25	10
11.6 GHZ	2.76	1.96	4.23	9
12.6 GHZ	2.66	1.72	3.59	9
13.6 GHZ	2.66	1.64	3.43	9
14.6 GHZ	2.55	[illegible]	3.29	8
15.6 GHZ	2.45	[illegible]	[illegible]	[illegible]
16.6 GHZ	[illegible]	[illegible]	2.21	7

ANTENNA HEIGHT= 30.4 METERS(100. FEET)

POLARIZATION= HH (21 INCH DISH)

INCIDENCE ANGLE= 10 DEGREES

FREQ.(GHZ)	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	5.01	5.50	[illegible]	4
4.4 GHZ	3.15	3.29	8.14	3
4.8 GHZ	2.97	3.10	7.23	3
5.2 GHZ	2.73	2.36	6.25	2
5.6 GHZ	2.60	2.74	5.53	2
6.0 GHZ	2.41	2.56	4.34	2
6.4 GHZ	2.29	2.37	4.26	2
6.8 GHZ	2.16	2.25	3.82	2
7.2 GHZ	2.04	2.13	3.41	2
7.6 GHZ	1.91	2.01	3.02	2
8.6 GHZ	1.67	1.76	2.31	1
9.6 GHZ	1.48	1.58	1.34	1
10.6 GHZ	1.56	1.46	1.56	1
11.6 GHZ	1.24	1.34	1.30	1
12.6 GHZ	1.17	1.23	1.13	1
13.6 GHZ	1.05	1.29	1.05	1
14.6 GHZ	0.99	1.22	0.94	1
15.6 GHZ	0.93	1.22	0.89	1
16.6 GHZ	0.86	1.16	0.73	1

INCIDENCE ANGLE= 20 DEGREES

FREQ.(GHZ)	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	5.51	5.56	24.06	9
4.4 GHZ	3.46	3.45	9.37	6
4.8 GHZ	3.26	3.25	8.33	6
5.2 GHZ	3.05	3.00	7.13	5
5.6 GHZ	2.85	2.87	6.43	5
6.0 GHZ	2.65	2.68	5.57	5
6.4 GHZ	2.51	2.49	4.90	4
6.8 GHZ	2.39	2.36	4.40	4
7.2 GHZ	2.24	2.23	3.92	4
7.6 GHZ	2.10	2.10	3.49	4
8.6 GHZ	1.85	1.85	2.66	3
9.6 GHZ	1.63	1.66	2.12	3
10.6 GHZ	1.49	1.53	1.79	3
11.6 GHZ	1.36	1.40	1.49	2
12.6 GHZ	1.29	1.34	1.36	2
13.6 GHZ	1.15	1.34	1.21	2
14.6 GHZ	1.09	1.27	1.09	2
15.6 GHZ	1.02	1.27	1.02	2
16.6 GHZ	0.95	1.21	0.90	2

INCIDENCE ANGLE= 30 DEGREES

FREQ.(GHZ)	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	6.50	6.04	30.80	16
4.4 GHZ	4.09	3.74	11.38	10
4.8 GHZ	3.84	3.53	10.65	10
5.2 GHZ	3.60	3.25	9.19	9
5.6 GHZ	3.36	3.11	8.21	8
6.0 GHZ	3.12	2.91	7.12	8
6.4 GHZ	2.96	2.70	6.27	7
6.8 GHZ	2.80	2.56	5.62	7
7.2 GHZ	2.64	2.42	5.02	7
7.6 GHZ	2.43	2.28	4.44	6
8.6 GHZ	2.16	2.01	3.40	5
9.6 GHZ	1.92	1.80	2.71	5
10.6 GHZ	1.76	1.66	2.29	4
11.6 GHZ	1.60	1.52	1.91	4
12.6 GHZ	1.52	1.45	1.73	4
13.6 GHZ	1.36	1.45	1.55	3
14.6 GHZ	1.28	1.38	1.39	3
15.6 GHZ	1.20	1.38	1.30	3
16.6 GHZ	1.12	1.31	1.15	3

INCIDENCE ANGLE= 40 DEGREES

FREQ.(GHZ)	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	8.32	6.83	44.66	27
4.4 GHZ	5.22	4.23	17.34	17
4.8 GHZ	4.91	3.99	15.40	16
5.2 GHZ	4.60	3.68	13.30	15
5.6 GHZ	4.29	3.52	11.88	14
6.0 GHZ	3.99	3.29	10.29	13
6.4 GHZ	3.73	3.05	9.06	12
6.8 GHZ	3.58	2.90	8.13	12
7.2 GHZ	3.37	2.74	7.25	11
7.6 GHZ	3.17	2.53	6.42	10
8.6 GHZ	2.76	2.27	4.91	9
9.6 GHZ	2.45	2.03	3.91	8
10.6 GHZ	2.25	1.88	3.31	7
11.6 GHZ	2.04	1.72	2.76	7
12.6 GHZ	1.94	1.64	2.50	6
13.6 GHZ	1.74	1.64	2.24	6
14.6 GHZ	1.65	1.56	2.01	5
15.6 GHZ	1.53	1.56	1.83	5
16.6 GHZ	1.45	1.40	1.67	5

INCIDENCE ANGLE= 50 DEGREES

FREQUENCY	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	17.32	11.07	173.48	66
4.4 GHZ	10.63	6.18	51.84	41
4.8 GHZ	9.79	5.71	43.87	38
5.2 GHZ	9.05	5.24	37.21	35
5.6 GHZ	8.46	4.95	32.90	32
6.0 GHZ	8.01	4.48	28.23	31
6.4 GHZ	6.69	4.30	22.57	26
6.8 GHZ	6.40	4.01	20.17	25
7.2 GHZ	6.25	3.73	18.33	24
7.6 GHZ	6.11	3.55	17.01	23
8.6 GHZ	5.03	3.03	12.29	19
9.6 GHZ	4.79	2.80	10.53	18
10.6 GHZ	4.50	2.52	8.90	17
11.6 GHZ	3.92	2.33	7.17	15
12.6 GHZ	3.77	2.05	6.08	14
13.6 GHZ	3.77	1.96	5.80	14
14.6 GHZ	3.63	1.96	5.58	14
15.6 GHZ	3.48	1.77	4.84	13
16.6 GHZ	3.05	1.58	3.79	12

INCIDENCE ANGLE= 60 DEGREES

FREQUENCY	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	19.98	15.64	281.43	86
4.4 GHZ	17.54	7.98	111.18	76
4.8 GHZ	16.29	7.36	94.20	71
5.2 GHZ	15.04	6.75	79.76	65
5.6 GHZ	14.05	6.39	70.45	61
6.0 GHZ	13.31	5.78	60.40	59
6.4 GHZ	11.10	5.53	48.20	48
6.8 GHZ	10.61	5.17	43.06	46
7.2 GHZ	10.35	4.81	39.12	45
7.6 GHZ	10.12	4.57	36.28	44
8.6 GHZ	8.42	3.96	26.19	36
9.6 GHZ	7.93	3.60	22.43	34
10.6 GHZ	7.45	3.24	18.95	32
11.6 GHZ	6.48	3.00	15.27	28
12.6 GHZ	6.24	2.64	12.93	27
13.6 GHZ	6.24	2.52	12.35	27
14.6 GHZ	6.00	2.52	11.87	26
15.6 GHZ	5.76	2.28	10.31	25
16.6 GHZ	5.04	2.04	8.06	22

INCIDENCE ANGLE= 70 DEGREES

FREQUENCY	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	26.44	24.02	569.18	124
4.4 GHZ	26.44	11.31	276.53	124
4.8 GHZ	26.44	10.88	249.31	124
5.2 GHZ	26.44	9.96	223.06	124
5.6 GHZ	25.94	9.41	204.07	122
6.0 GHZ	25.36	8.51	179.33	119
6.4 GHZ	23.57	8.12	152.24	111
6.8 GHZ	22.87	7.59	136.27	108
7.2 GHZ	22.33	7.06	123.75	105
7.6 GHZ	21.80	6.70	114.71	103
8.6 GHZ	18.09	5.81	82.49	85
9.6 GHZ	17.04	5.29	70.60	80
10.6 GHZ	15.99	4.75	59.59	75
11.6 GHZ	13.90	4.39	47.93	65
12.6 GHZ	13.38	3.86	40.59	63
13.6 GHZ	13.33	3.69	38.75	63
14.6 GHZ	12.36	3.69	37.23	60
15.6 GHZ	12.34	3.33	32.32	58
16.6 GHZ	10.79	2.98	25.26	51

INCIDENCE ANGLE= 80 DEGREES

FREQUENCY	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	48.87	71.67	2110.74	240
4.4 GHZ	48.87	24.77	1039.65	240
4.8 GHZ	48.87	22.72	1007.26	240
5.2 GHZ	48.85	20.61	917.25	240
5.6 GHZ	48.85	19.34	864.52	240
6.0 GHZ	48.85	17.41	780.65	240
6.4 GHZ	48.85	16.47	775.26	240
6.8 GHZ	48.85	15.71	687.69	240
7.2 GHZ	48.37	14.22	634.09	240
7.6 GHZ	48.85	13.49	600.45	240
8.6 GHZ	48.85	11.61	504.65	240
9.6 GHZ	48.77	10.57	[illegible]	240
10.6 GHZ	[illegible]	9.46	[illegible]	[illegible]
11.6 GHZ	47.67	8.77	[illegible]	[illegible]
12.6 GHZ	[illegible]	7.67	[illegible]	[illegible]
13.6 GHZ	46.71	7.72	[illegible]	231
14.6 GHZ	46.19	7.32	[illegible]	227
15.6 GHZ	45.35	6.61	219.13	225
16.6 GHZ	42.72	[illegible]	175.17	[illegible]

INCIDENCE ANGLE= 50 DEGREES

FREQ.(GHZ)	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	11.37	8.16	76.12	46
4.4 GHZ	7.43	5.05	29.42	29
4.8 GHZ	6.93	4.76	25.13	27
5.2 GHZ	6.55	4.39	22.56	25
5.6 GHZ	6.11	4.20	20.15	25
6.0 GHZ	5.67	3.92	17.45	22
6.4 GHZ	5.33	3.64	15.36	21
6.8 GHZ	5.03	3.45	13.78	19
7.2 GHZ	4.79	3.26	12.29	18
7.6 GHZ	4.50	3.08	10.83	17
8.6 GHZ	3.92	2.70	8.32	15
9.6 GHZ	3.48	2.42	6.63	13
10.6 GHZ	3.19	2.24	5.61	12
11.6 GHZ	2.90	2.05	4.67	11
12.6 GHZ	2.76	1.96	4.24	11
13.6 GHZ	2.47	1.96	3.79	9
14.6 GHZ	2.32	1.86	3.40	9
15.6 GHZ	2.18	1.86	3.18	8
16.6 GHZ	2.03	1.77	2.82	8

INCIDENCE ANGLE= 60 DEGREES

FREQ.(GHZ)	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	19.29	10.55	153.24	79
4.4 GHZ	12.32	6.50	62.89	53
4.8 GHZ	11.59	6.13	55.82	50
5.2 GHZ	10.85	5.65	48.16	47
5.6 GHZ	10.12	5.41	42.98	44
6.0 GHZ	9.39	5.04	37.20	41
6.4 GHZ	8.30	4.68	32.75	39
6.8 GHZ	8.42	4.44	29.37	36
7.2 GHZ	7.93	4.20	26.17	34
7.6 GHZ	7.45	3.96	23.17	32
8.6 GHZ	6.48	3.48	17.71	28
9.6 GHZ	5.76	3.12	14.10	25
10.6 GHZ	5.23	2.88	11.93	23
11.6 GHZ	4.80	2.64	9.94	21
12.6 GHZ	4.56	2.52	9.01	20
13.6 GHZ	4.08	2.52	8.06	18
14.6 GHZ	3.84	2.40	7.22	17
15.6 GHZ	3.60	2.40	6.77	16
16.6 GHZ	3.36	2.28	6.00	15

INCIDENCE ANGLE= 70 DEGREES

FREQ.(GHZ)	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	26.44	15.65	372.37	124
4.4 GHZ	24.53	9.56	192.74	115
4.8 GHZ	23.98	9.01	174.58	113
5.2 GHZ	23.37	8.30	152.49	110
5.6 GHZ	21.80	7.94	135.87	103
6.0 GHZ	20.20	7.40	117.41	95
6.4 GHZ	19.14	6.87	103.25	90
6.8 GHZ	18.09	6.51	92.50	85
7.2 GHZ	17.04	6.16	82.37	80
7.6 GHZ	15.99	5.80	72.85	75
8.6 GHZ	13.90	5.09	55.60	65
9.6 GHZ	12.34	4.55	44.23	58
10.6 GHZ	11.31	4.21	[illegible]	53
11.6 GHZ	10.27	3.86	31.13	48
12.6 GHZ	9.75	3.63	28.21	46
13.6 GHZ	8.72	3.68	25.22	41
14.6 GHZ	9.21	3.51	22.60	39
15.6 GHZ	7.69	3.51	21.19	36
16.6 GHZ	7.13	3.33	18.77	34

INCIDENCE ANGLE= 80 DEGREES

FREQ.(GHZ)	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	48.35	33.75	1441.79	240
4.4 GHZ	49.83	19.45	972.12	240
4.8 GHZ	49.87	18.27	919.92	240
5.2 GHZ	49.83	16.76	749.33	240
5.6 GHZ	49.33	15.93	711.06	240
6.0 GHZ	48.83	[illegible]	656.09	240
6.4 GHZ	49.31	13.75	[illegible]	240
6.8 GHZ	[illegible]	13.02	565.79	240
7.2 GHZ	[illegible]	[illegible]	[illegible]	240
7.6 GHZ	[illegible]	11.56	[illegible]	210
8.6 GHZ	[illegible]	10.12	[illegible]	235
9.6 GHZ	[illegible]	9.05	[illegible]	225
10.6 GHZ	[illegible]	[illegible]	[illegible]	216
11.6 GHZ	[illegible]	[illegible]	[illegible]	[illegible]
12.6 GHZ	[illegible]	[illegible]	[illegible]	[illegible]
13.6 GHZ	[illegible]	[illegible]	[illegible]	[illegible]
14.6 GHZ	[illegible]	[illegible]	[illegible]	[illegible]
15.6 GHZ	[illegible]	[illegible]	[illegible]	[illegible]
16.6 GHZ	[illegible]	[illegible]	[illegible]	[illegible]

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